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Verification of the Effects of Snowboard Training Simulators

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Abstract

The purpose of the present study was to compare riding postures while training in a simulator and on snow for snowboarding, which takes place on snow, to verify the training effects of simulators. Four professional snowboarding players were selected as study subjects. The purpose of this study was to verify the effects of snowboarding simulators. Two analysis methods were applied: motion analysis using motion-capture cameras and analysis of muscle activity using an electromyogram (EMG) analysis system. . From analysis of the data, the following conclusions were drawn.First, snowboarding posture training in simulators helps improve riding angulation (tilting using ankle flexion). Second, practicing snowboard riding on horizontal simulators before riding on slopes, taking into account the difficulty of training motions and participants' level of proficiency in them, is desirable. Third, during practice of snowboard riding motions using simulators, instructors should continuously evaluate and correct participants' posture to prevent excessive hip-joint flexion during FS turns.Fourth, most muscles showed higher activity levels during snowboard riding on slopes than in simulators. Physical resistance induced by increasing the slope of simulators seems capable of increasing training effects.

Keywords*: Snowboard, EMG, simulator, motion capture, angle of joint*

1. Introduction

Snowboardinghas become a popular winter sport, especially among youths. Snowboarding games were first adopted as an official sport in the 1998 Nagano Winter Olympic Games. In the 2018PyeongchangWinter Olympic Games, 10 gold medals will be awarded to men and women in five snowboarding events: parallel slalom, parallel giant slalom, snowboard cross, half-pipe, and slope styles. Among those events, parallel slalom, parallel giant slalom, and snowboard cross are alpine events in which speed is very important. This highly active sport involves high injury risks for participants who lack systematic training. In its short history, snowboarding has drawn attention as a sport which encourages thrill-seeking (Bladin, McCrorym, &Pogorzelski, 2004; Pressman & Johnson, 2003).

The characteristics of snowboarding games make not only anaerobic exercise capability but also aerobic exercise capability highly important. These games demand numerous functional elements of active physical fitness: agility for starts, downhill skiing, and jumps; coordination and flexibility for arm and leg movements; and balance to maintain the body on the snowboard. The games involve competing forspeed records and performing techniques on snow or structures made of snow, so the development of specialized physical fitness appropriate for these events is crucial to improving athletic performance. However, it is difficult to construct ideal practice environments for training on snow. Poor practice environments decrease the efficiency of training and can lead to a higher probability of injury. Therefore, ground training is necessary as an ancillary to

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training on snow to improve specialized physical fitness skills and correct postures. As can be seen in recent cases of elite skiers who have achieved excellent results by applying sports science to their training, sports-science-based training, measurement, and evaluation systems and tools are necessary not only to prevent injuries and increase motor ability among the general public but also to improve thetraining, ability, and athletic performance of elite players (Lee, Nam, Jeon,& Choi, 2014).

However, snowboarding-related studies are quite insufficient because sport-science analysis methods for events on snow cannot easily obtain accurate data due to natural environmental constraints. Doki, Yamada, Nagai, andHokari(2004) analyzed joint angles and joint torques during a kinetic analysis of snowboard turning motions, while Cho (2011)examined lower-limb joint angles, angular speed, times by section, and displacement of the body's center of gravity. Emphasizing the importance of posture, Cho (2011) advised that, to perform excellent snowboard turns, turns toward the mountain should be completed to displace the body's center of gravity, tilts appropriate for the speed should be applied to account for the different trajectories of the board and the body's center of gravity, and differences in tilts should be increased for back turns. These researchers could not study many variables due to constraints on analysis equipment caused by environmental factors. As well, these findings cannot easily be used in the field where immediate feedback is required because great amounts of time and effort are necessary to derive study results.

As mentioned, scientific training protocols are highly important for the improvement of snowboarding techniques and the prevention of injuries. In addition, training on snow can be done for only three months a year in South Korea due to natural environmental constraints. To substitute for training on snow in this present study, snowboarding simulators for ground training methods were made in the laboratory. The purpose of the present study was to compare riding postures while training in a simulator and on snow for snowboarding, which takes place on snow, to verify the training effects of simulators.

2. Study Method

2.1. Study Subjects

Four professional snowboarding players were selected as study subjects.The participants had no difficulty performing snowboarding motions and had not experienced musculoskeletal disease within six months before the experiment. Before the main experiment, verbal explanation of the experimental procedure was given to the subjects, who voluntarily agreed and signed written agreements to participate in the experiment.

2.2. Experimental Tool

The purpose of this study was to verify the effects ofsnowboarding simulators. Two analysis methods were applied: motion analysis using motion-capture cameras and analysis of muscle activity using an electromyogram (EMG)analysissystem.

First, in themotion analysis, eight units of Oqus 322 5 series cameras from Qualisys(Sweden) were used, and the shooting speed was set to 150Hz. Individual motion-capture cameras were synchronized through LAN cables, data were transmitted between the cameras and a computer, and three-dimensional (3D) spatial coordinate values of individual markers were obtained using Qualisys Track Manager(QTM) software. Second, a Noraxon EMG system (Telemyo 2400T system, Noraxon, USA) was used to analyze the muscle activity of lower-limb muscles. Bipolar surface electrodes were attached to the surface of participants' skin to collect EMG signals. Data were transmitted through Wi-Fi wireless communication systems, and the sampling rate was set to 1000Hz.

2.3. Experimental Procedure

Simulators dedicated to snowboarding were made to conduct ground snowboardingtraining, and tests were performed to verify the effects of the training. For the purposes of comparison and verification, the experiments were conducted under three conditions: actual slope situations, simulators parallel to the ground, and simulators at a 15°slope. The experiment was conducted in three steps. First, snowboard riding was performed in actual slope situations while motion analysis andEMGanalysis were conducted. Next, the simulator experiment was conducted atthe Kinetics Laboratory of S University under two conditions. A detailed experimental layout is shown in Figure 1.

Figure 1. Experimental Layout

2.4. Data Analysis

For the purposes of comparison and verification, the experiment was conducted under three conditions: actual slope situations, simulators parallel to the ground, and simulators at a 15° slope. Foursnowboarding players participated in the experiment. Event1 (E1) was set toneutral, event2(E2)was set to maximum tilt, event3(E3) was set to neutral, and event 4(E4) was returned to turn maximum slope. The 3D dimensional spatial coordinate values extracted using motion-capture cameras and QTM software were converted intoC3D format, and various variables were analyzed using Visual3D(C-Motion Inc., USA). The EMG data were analyzed using the MR 3.4.5 program (Noraxon, USA), andsignals in the frequency domain range corresponding to 20Hz –500Hz were analyzed using bandpass filters. In addition, Microsoft Excel 2010(Microsoft Inc., USA) and Matlab R2012a (Mathworks Inc., USA) were used to process other data.

2.4.1 Event setting: Four events were designed for snowboard riding on actual slopes and snowboard-riding motions in the simulators. Events 1 and 3 were set to snowboard riding in neutral positions similar to standing posture, whileevent 2 was set to maximum tilting onfront turns, and event 4 was set to maximum tilting on back turns (Figure 2).

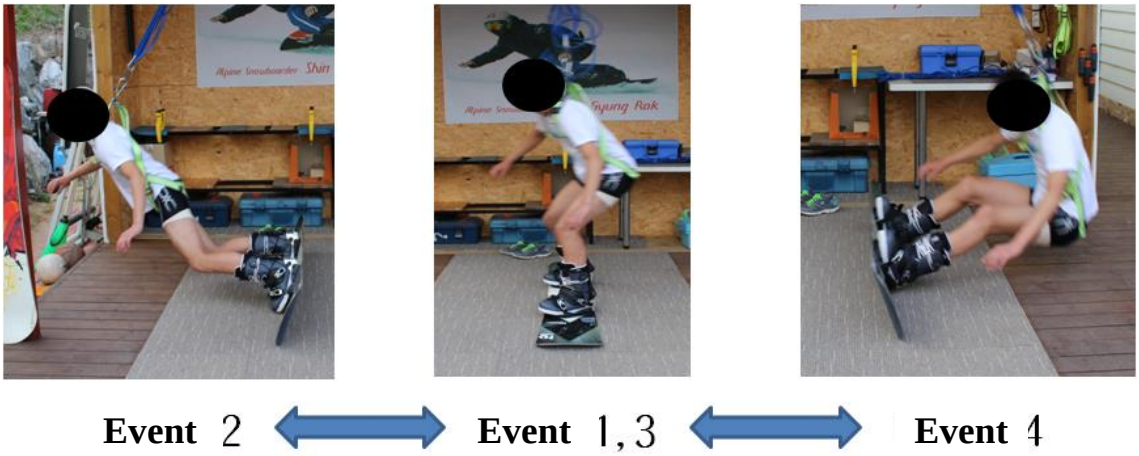

Figure 2. Event Setting

2.4.2 Kinematic variables: Kinematic variables were derived to detect changes in participants' postures during actual riding motions. The derivedkinematic variables are lower-limb joint angles in individual events, specifically,ankle, knee, and hip-joint flexion-extension angles. Both right and left angles were calculated for all variables.

2.4.3 EMG variable: To examine levels of muscle activity during snowboard riding, EMG analysis was applied to eight muscles: the left and right musculus rectus femoris, musculus biceps femoris, musculus tibialis anterior, and musculus gastrocnemius. Full-wave rectification was conducted to prevent distortion of the quantification of raw EMG data due to negative values while maintaining all signal characteristics.Noises were removed by filtering with band pass filters (20~500 Hz). Finally, the rectified signals with noises removed were integrated for certain time sections to obtain integral EMGs, as shown in the following equation.

$$iEMG = \int_{t}^{t+\tau} |EMG(t)| \cdot dt \quad (1)$$

3. Study Results and discuSsion

To verify the effects of snowboardingtraining simulators on posture, lower-limb joint angles in snowboard-riding postures on an actualslope, in a horizontal simulator, and in a simulator at a 15°slope were compared and analyzed. The results were as follows in Table 1.

Table 1. Lower-Limb Joint Angles (Degree) Under Different Simulator Conditions

		Slope	Plane simulator	15°simulator	Significance probability	Post-hoc test(Scheffe)
Event1	Right ankle	96.52±25.30	107.64±6.98	99.35±6.45	0.596	
	Right knee	123.88±5.27	125.93±12.30	74.99±9.63	0.000	15° <slope<plane
	Right hip	122.33±37.09	136.88±18.87	191.24±4.57	0.007	slope<plane<15°
	Left ankle	100.03±18.26	103.71±6.79	73.91±6.23	0.012	15° <slope<plane
	Left knee	135.12±10.32	131.19±13.87	95.56±8.29	0.001	15° <slope<plane

	Left hip	129.84±29.76	136.70±20.38	161.15±14.49	0.172	
Event2	Right ankle	95.78±11.83	98.60±13.46	97.06±4.93	0.933	
	Right knee	128.71±9.59	120.90±11.19	77.20±5.93	0.000	15° <plane<slope
	Right hip	126.86±31.74	116.61±27.61	195.26±7.92	0.003	plane<slope<15°
	Left ankle	106.10±5.05	118.56±26.01	79.96±5.84	0.019	15° <plane
	Left knee	145.51±9.17	139.52±15.62	96.15±3.59	0.000	15° <plane<slope
	Left hip	127.83±17.40	117.37±22.28	159.86±7.67	0.016	plane<15°
Event3	Right ankle	95.78±11.83	108.42±3.73	98.17±4.20	0.092	
	Right knee	100.79±8.92	128.71±9.59	130.00±26.16	0.002	15° <slope<plane
	Right hip	78.40±4.67	112.37±29.11	126.86±31.74	0.004	slope<plane<15°
	Left ankle	134.02±21.41	194.17±5.55	151.68±37.44	0.000	15° <plane<slope
	Left knee	106.10±5.05	105.78±4.38	77.51±7.98	0.004	15° <plane<slope
	Left hip	96.46±15.02	145.51±9.17	134.16±25.56	0.035	slope<15°
Event4	Right ankle	113.21±4.21	107.86±13.58	99.00±6.48	0.134	
	Right knee	122.81±17.25	96.78±11.28	75.17±8.88	0.002	15° <slope
	Right hip	114.10±31.51	114.99±21.62	193.84±6.50	0.001	slope<plane<15°
	Left ankle	110.64±28.65	103.09±12.00	77.78±9.95	0.082	
	Left knee	131.73±15.30	102.55±14.50	95.26±9.25	0.009	15° <plane<slope
	Left hip	110.14±23.67	115.58±21.85	162.84±6.31	0.006	slope<plane<15°

E1 andE3covered neutral sections (neutral position) in which the turns were not tilted in any direction, and the COG was the highest. E2had the lowest COG among BS sections, whilee4had the lowest COG among FS turn sections.

Right-ankle and left-hip flexion angles were not significantly different between the neutral sections E1 andE3, while right-ankle flexion angles in E2 and E4 were not significantly different from left-hipflexion angles in E4. The results indicate that right-ankle flexion angles were not significantly different under the actual slope, horizontal simulator, and 15°-slope simulatorconditions.A likely explanation of these results is that, in most snowboard-riding postures, the right ankle is an important lower limb joint whichtransfers pressure from the body to the snowboardthrough the last time point, manipulating the snowboard.All the experimental participantsassumed regular stances centering on the right foot to ride the snowboard. Snowboard posture training performed insimulators seems capable of contributing greatly to the improvement of ridingangulation (tilting usingankle flexion).

According to the results of the post-hoc tests forBS turn sections, right-andleft-knee andleft-ankleflexion angles were significantly smaller in the 15°-slope simulator condition than in actual-slope and horizontal-simulator riding postures. Joint flexion angles were shown to be smaller in the 15°-slope simulators than actualslope situations where the effects of larger forces on larger slopes made maintaining accurate postures more difficult. Therefore,practice using the simulators could contribute to the

improvement of joint flexibility and correction of posture. In particular, given that right-andleft-knee joint flexion angles in riding posture were the largest, in order, on actualslopes, horizontal simulators, and 15°-slope simulators, it is desirable to practice snowboard riding on horizontal simulators before riding on slopes, taking into account the levels of difficulties of trainingmotions and proficiency in them.

According to the results of post-hoc tests forFS turn sections, right-knee and left-knee flexion angles were significantly smaller in 15°-slope simulator conditions than actual-slope riding postures. The foregoing situations can be regarded as similar to actual-slope situations where external forces are larger when slope angles are larger. According to the post-hoc test results, right-and left-hip joint flexion angles were significantly smaller on actualslopes than in horizontal simulators and 15°-slope simulators. This difference can be attributed to the nature of FS turns made on slopes, in which force is expressed through the turning of the upper body, rather than the flexion of both hip joints.In contrast, FS turns on horizontal slopes or 15°-slope simulators are made through the flexion of hip joints due to the physical resistance of this design. During practice of snowboard-riding motions using simulators, instructors should continuously evaluate and correct participants'postureto prevent excessive hip-joint flexion during FS turns.

To verify the training effects of snowboard-posturetraining simulators, the activity level of individual lower-limb muscles during riding postures onactualslopes, a horizontal simulator, and a simulator with a 15°-slope were compared and analyzed. The results are as follows in Table 2.

Table 2. Lower-Limb Muscle Activity (Mv*S) During Simulator Training Under Three Conditions

		RT RECTUS FEM.,uV	RT BICEPS FEM.	RT TIB.ANT.	RT LAT. GASTRO	LT RECTUS FEM.	LT BICEPS FEM.	LT TIB.ANT.	LT LAT. GASTRO
15°	Back Turn	74.19	48.29	254.8	42.58	106.61	54.135	262.95	51.715
Plane		18.67	23.86	70.69	54.03	34.84	29.58	48.88	46.63
Slope		30.78	96.50	118.95	152.78	31.08	81.79	87.95	34.13
		RT RECTUS FEM., uV	RT BICEPS FEM.	RT TIB.ANT.	RT LAT. GASTRO	LT RECTUS FEM.	LT BICEPS FEM.	LT TIB.ANT.	LT LAT. GASTRO
15°	Front Turn	55.51	22.4185	147.93	37.95	43.54	28.7805	126.04	49.735
Plane		9.91	26.17	60.94	59.48	22.50	36.63	52.68	59.51
Slope		45.15	101.84	120.98	150.40	35.61	137.29	97.38	30.72

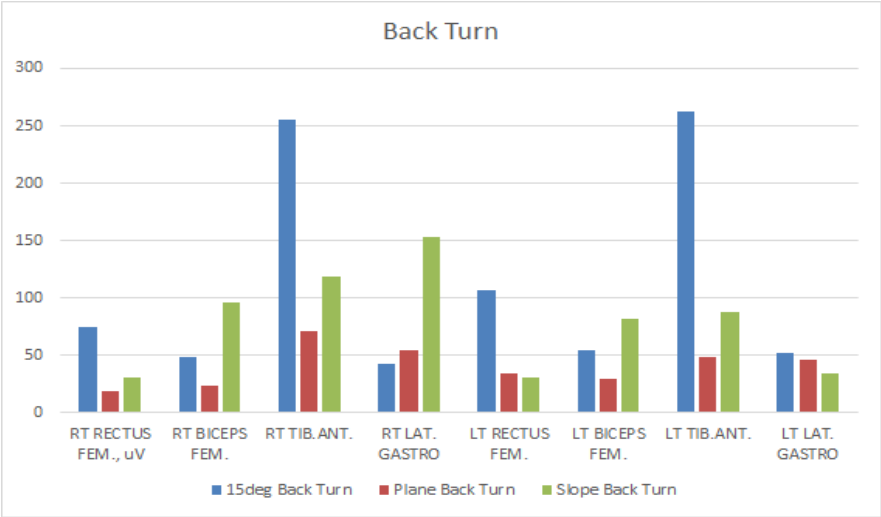

Figure 3. Lower-Limb Muscle-Activity Levels during Back Turns Under Three Conditions

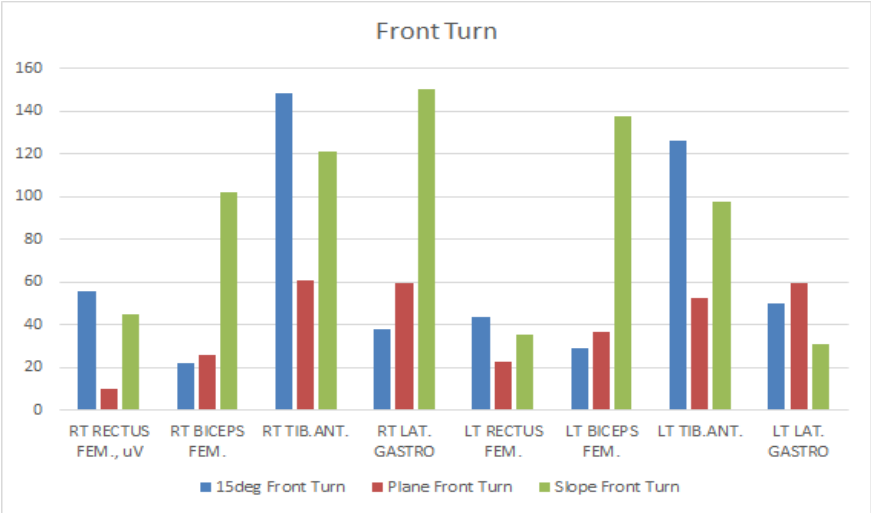

Figure 4. Lower-Limb Muscle Activity Levels during Front Turns Under Three Conditions

In BS turn sections, the activity levels of the right and left musculus rectus femoris and the right and left musculus tibialis anterior were shown to be the highest on the15°-slope simulator. All muscles, except for the leftmusculus rectus femoris and the leftlateral musculus gastrocnemius, showed higher levels of muscle activity during snowboard riding on slopes than simulators. In FS turn sections, the muscle activity levels of the right and left musculus rectus femoris and the right and the left musculus tibialis anterior were shown to be the highest on the 15°-slope simulators. Most muscles showed higher activity levels during snowboard riding on slopes than those simulators. Based on stimulation of the major lower-limb muscles used in snowboard riding, physical resistance induced by increasing the slope ofsimulators seems capable of increasing training effects.

4. Conclusions and Proposal

The present study was aimed to compare riding postures during snowboard ground training in simulators and on actual snow in order to verify the training effects of

simulators. To that end, motion analysis and EMG analysis were conducted to examine riding postures on slopes, horizontal simulators, and simulators with a 15°-slope and to measure lower-limbjoint angles andmuscleactivity.From analysis of the data, the following conclusions were drawn.

First, snowboarding posture training in simulators helps improve ridingangulation (tilting usingankle flexion).

Second, practicing snowboard riding on horizontal simulators before riding on slopes, taking into account the difficulty of training motions and participants' level of proficiency in them,is desirable.

Third, during practice of snowboard riding motions using simulators, instructors should continuously evaluate and correct participants' posture to prevent excessive hip-joint flexion during FS turns.

Fourth, most muscles showed higher activity levels during snowboard riding on slopes than in simulators. Physical resistance induced by increasing the slope of simulators seems capable of increasing training effects.

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