A Case Study of Alpine and Freestyle Snowboard Turn Measurement

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Abstract: This study investigated the reaction force from the snow surface affecting a snowboarder during alpine snowboarding turns and freestyle snowboarding turns. Alpine snowboards and freestyle snowboards have different widths, shapes, flexes, and hardnesses. Snowboarder motions during turns using an alpine snowboard and freestyle snowboard differ. Therefore, analyzing the reaction force from the snow surface affecting the snowboarder gliding on an actual snow field is expected to be valuable for clarifying differences of snowboarder motions during alpine snowboarding turns and freestyle snowboarding turns. We developed a new measurement system for this study to measure the reaction force from the snow surface during snowboarding. Furthermore, we conducted experiments with a professional snowboarder gliding on an actual snow field using alpine and freestyle snowboards fitted with the measurement system. The center of pressure during alpine snowboarding showed that the right foot placed on the snowboard in the counter travel direction side was used mainly to press the snowboard edge during front-side turns. The left foot placed on the snowboard in the travel direction side was used mainly to press the snowboard edge during back-side turns. The center of pressure during freestyle snowboarding showed that both feet were used to press the snowboard edge.

1 INTRODUCTION

Snowboarding, which involves descending a snow-covered slope on a board attached to both feet, requires alpine or freestyle snowboards, both of which are widely used. Alpine snowboarders wear hard boots similar to those used conventionally for alpine skiing, with dedicated bindings for hard boots. Freestyle snowboarders wear soft boots and dedicated bindings for soft boots. Moreover, alpine snowboards are narrower than freestyle snowboards. Therefore, alpine bindings are attached to a board at a much higher angle in the travel direction to avoid heel or toe drag. In giant slalom events, alpine snowboards are used because alpine snowboard characteristics are suitable for speed and tight curves. By contrast, freestyle snowboards are suited to jumping and ground tricks because freestyle snowboarders can move their ankles freely with soft boots. Alpine and freestyle boards have numerous points of difference such as board characteristics, boots, and bindings. Moreover, snowboard control methods differ among snowboard types. Clarifying the respective snowboard turn mechanisms of alpine and freestyle snowboarding is therefore important for evaluating snowboarder skills.

Several earlier reports describe studies of skiing and snowboarding (Subic et al., 2010; Fuss, 2014; Saito et al., 2015; Korecki et al., 2016). Kagawa et al. (1998) developed a force sensor incorporating several strain gauges to measure the six-component forces of a skier during turns. Other studies have used several uniaxial load cells or six-component force sensors to analyze the reaction force from a snow surface on a skier gliding on an actual snow field (Iwami et al., 2002; Kiefmann et al., 2006). These studies revealed how skiers put pressure on the skis during gliding on an actual snow field. For earlier studies of snowboarding, force sensors were used to measure the reaction force from a snow surface on snowboarders in the same manner as those used for earlier studies of skiing. Moeyersons et al. (2016) developed an electronic system to analyze the reaction force from a snow surface on snowboarders.

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It alerted the snowboarders when a greater load was put on the back boot than on the front boot. Hirose et al. (2013a, 2013b) estimated the joint torques of snowboarders and skiers during turns using inertial sensors and six-component force sensors. Kondo et al. (2014) developed a new system of measuring the reaction force from a snow surface for snowboarding using compact three-component force sensors. Other studies have assessed the six-component force characteristics of snowboarders during turns and jumping (Hirose et al., 2016; Fushimi et al., 2017). Nevertheless, few studies have examined alpine snowboards. For this study, we conducted experiments with one professional snowboarder using an alpine snowboard and a freestyle snowboard as the first step toward clarifying snowboard turn mechanisms. This experiment elucidates whether the reaction force from the snow surface can be different in alpine snowboarding turns and freestyle snowboarding turns. The new reaction force measurement system was developed for this study by installing six-component force sensors. This measurement experiment analyzed the six-component force of a professional snowboarder during turns made on an actual snow field. Furthermore, to quantify the difference of each snowboarding, we compared the center of pressure (COP) of the snowboarder, as calculated from the six-component force during alpine and freestyle snowboarding turns.

2 METHOD

2.1 Measurement System

The snowboarding reaction force measurement system is presented alone in Fig. 1 and attached to the snowboard in Fig. 2. The system consists of an upper plate, a lower plate, and a six-component force sensor (FFS080YS102U6; Leptrino Co. Ltd.). The upper plate is attached to a binding. The lower plate is attached to a snowboard. The six-component force sensor is installed between the upper plate and the lower plate. The 120 mm × 120 mm × 34 mm system had total weight of 970 g including the six-component force sensor. We developed two measurement systems: one attached to the travel direction side (left) binding and one attached to the counter travel direction side (right) binding. Upper plates were made of machined aluminum. Using a personal 3D printer, lower plates were produced from acrylonitrile butadiene styrene (ABS) resin. The systems were used with alpine and freestyle snowboards.

The reaction force from the snow surface was expressed as a six-component force (3-axis force and 3-axis moment) measured using the force sensors.

2.2 Experiment

The measurement experiment assessed a professional snowboarder (181 cm height, 86 kg weight) gliding on an actual snow field. The snowboarder, who had 28 years of snowboarding experience, held a Grade-A instructor license authorized by the Japan Snowboarding Association. The snowboarder used a regular stance, with the left foot placed on the snowboard in the travel direction. Following an explanation of the purpose and requirements of the study, the snowboarder gave written informed consent to participate. Study approval was obtained from the Research Ethics Board, National Institute of Akita College. The alpine snowboard used for the experiment (Eracer 163 cm; Yonex Co., Ltd.) is depicted in Fig. 3.

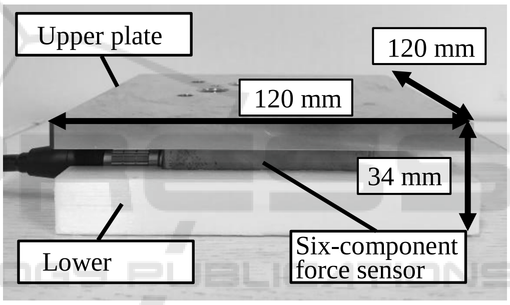


Figure 1: Snow surface reaction force measurement system.

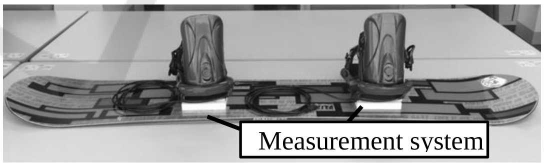


Figure 2: Measurement system between the snowboard and bindings.

The freestyle snowboard (Meister 161 cm; Yonex Co., Ltd.) is portrayed in Fig. 4. Measurement systems were installed between the bindings and snowboards for both feet. The snowboarder with the measurement system is presented in Fig. 5.

The definitions of binding angles are presented in Fig. 6. An angle of 0 deg signifies that the binding is mounted as pointing directly across the snowboard with no forward or no backward angle. A binding angle with plus degrees (+) signifies that the binding is set pointing to the nose of the snowboard. For this experiment, the travel direction side angle was plus

54 deg; the counter travel direction side angle was plus 48 deg on the alpine snowboard. The travel direction side angle was plus 21 deg; the counter travel direction side angle was 0 deg on the freestyle snowboard.

A schematic view of the slalom slope, with average inclination of about 12 deg, is presented in Fig. 7. The snowboarder made periodic carving turns. The sampling frequency was 100 Hz.

Figure 3: Alpine snowboard used in the experiment.

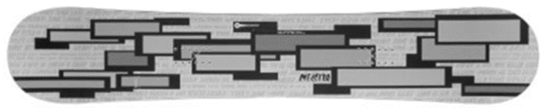


Figure 4: Freestyle snowboard used in the experiment.

Figure 5: Snowboarder with attached measurement system.

2.3 Analysis Method

The coordinate system of the measurement system is presented in Fig. 8. The six-component forces of the snowboarder were compared to clarify their respective motion characteristics. Furthermore, we analyzed COP calculated from the six-component forces. Earlier studies showed that snowboarders make turns using a moment around the snowboard length direction (Hirose et al., 2014; Kondo et al., 2014). For this study, the Y-axis is the snowboard length direction. Therefore, we specifically examined the COP of the width direction (X-axis).

The COP of the width direction is represented by Eq. (1), where a_z is the direction from the original point to the force sensor of z-axis direction, f_x and f_z respectively represent the x-axis force and y-axis force, respectively and n_y is the y-axis moment.

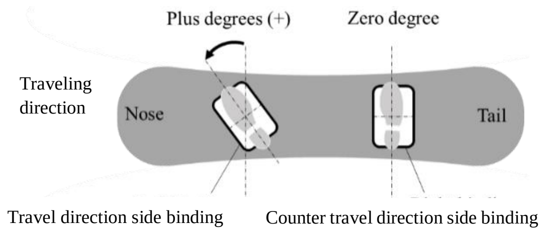


Figure 6: Definitions of binding angles.

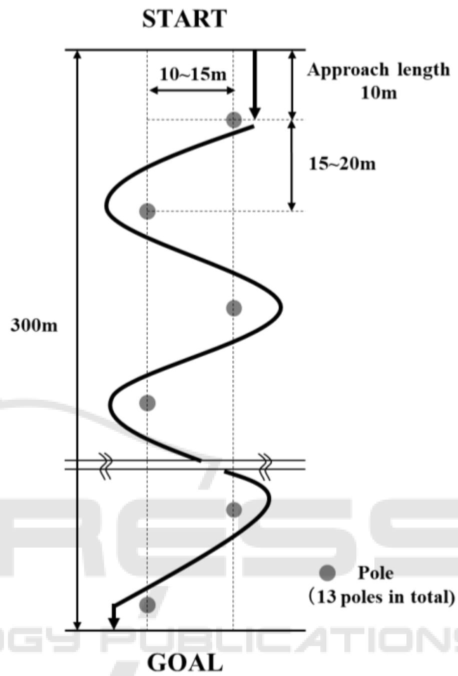


Figure 7: Schematic view of the slalom slope.

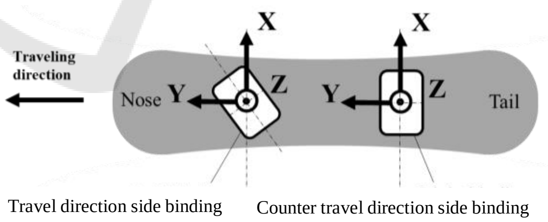


Figure 8: Snowboard with attached measurement system.

$$a_x = \frac{f_x a_z - n_y}{f_z} \quad (1)$$

3 RESULTS

Fig. 9 presents results for the reaction force from the snow surface of turns during alpine snowboarding. Figure 10 presents results for the reaction force from the snow surface during turns in freestyle snowboarding. Measurement experiments were repeated three times for each type of snowboarding. All results of alpine snowboarding indicated a similar tendency. All results of freestyle snowboarding also indicated a similar tendency. The results of the third trial of both snowboards are presented in Fig. 9 and Fig. 10, where the horizontal axis is the time axis and the vertical axis shows the six-component force.

These results represent the outcomes of four turns as the snowboarder passed from the sixth pole through the ninth pole. The snowboarder made front-side turns while passing through the sixth pole and the eighth pole. Front-side turns were made by pressing on the toe-side edge. The snowboarder made back-side turns while passing through the seventh pole and the ninth pole. Back-side turns were done by pressing on the heel-side edge.

The switching point between a front-side turn and a back-side turn was defined as the time when the value of Y-axis moment became zero. The switching points of turns on the left foot were defined using the value of Y-axis moment on the left foot. The switching points of turns on the right foot were defined using the value of Y-axis moment on the right foot.

Table 1 presents results for the X-axis coordinate of the COP of the averages of all trials. The X-axis coordinate of the COP was calculated using measurement information of 10% before and after the midpoint of the time for each turn.

4 DISCUSSION

4.1 Reaction Force from the Snow Surface

The Z-axis force of the counter travel direction side foot increased during turns in alpine and freestyle snowboarding. The Z-axis force of the travel direction side foot showed little characteristic change during turns in alpine and freestyle snowboarding. Results indicate that the counter travel direction side foot was used mainly to put pressure on the snowboard.

The Y-axis moment of both feet changed periodically to put pressure on the snowboard edges in alpine and freestyle snowboarding. The Z-axis moments of both feet in freestyle snowboarding changed periodically, whereas the Z-axis moments of both feet showed only slight changes in alpine snowboarding. In freestyle snowboarding, the Z-axis moment of the travel direction side foot increased in front-side turns. The Z-axis moment of the counter travel direction side foot increased in back-side turns. Results demonstrate that the snowboarder moved the ankles to control the snowboard during freestyle snowboarding. Presumably, the snowboarder repositioned the ankles for ease of pressing on the snowboard.

4.2 Center of Pressure

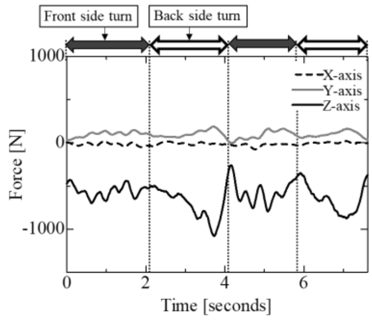
For alpine and freestyle snowboarding, the X-axis COP coordinates had plus values during front-side turns, with X-axis COP coordinates having minus values during back-side turns. Results show that the X-axis COP coordinates moved to the inside of turns during turns to put pressure on the snowboard edges.

In front-side turns of alpine snowboarding, the COP of the travel direction side foot stayed in the position close to the origin of the coordinate, although the COP of the counter travel direction side foot stayed in the position close to the edge. In back-side turns during alpine snowboarding, the COP of the travel direction side foot stayed in the position close to the snowboard edge, although the COP of the counter travel direction side foot stayed in the position close to the origin of the coordinate. Results show that the counter travel direction side foot was used mainly to put pressure on the snowboard edge during front-side turns. The travel direction side foot was used mainly to put pressure on the snowboard edge during back-side turns.

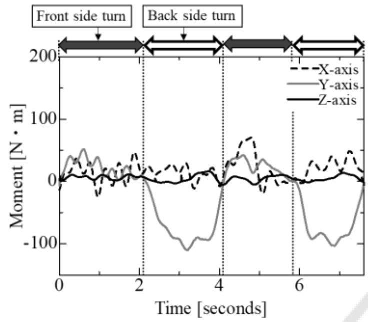
However, the COP of both feet stayed in the position close to the snowboard edge during both turns in freestyle snowboarding. Results show that both feet were used to put pressure on the snowboard edge.

5 CONCLUSIONS

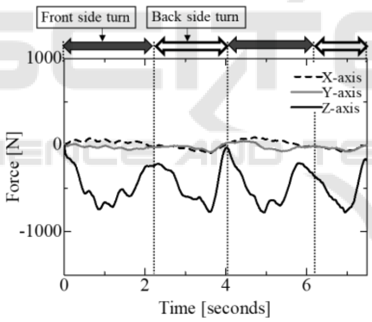
Measurement experiments were conducted with a professional snowboarder to clarify differences in the reaction force from the snow surface during turns executed for alpine and freestyle snowboarding. The results elucidated the characteristics of the three-axis force and the three-axis moment of a snowboarder during turns. Furthermore, the COP results reflected the degree to which the snowboarder put pressure on the snowboard edge. This study revealed that the reaction force from the snow surface and the COP are useful to ascertain the snowboarder motion characteristics during turns. Additional studies measuring other snowboarders must be done for quantitative clarification of reaction forces from the snow surface and assessment of the differences of snowboarder motions in alpine snowboarding turns and freestyle snowboarding turns.



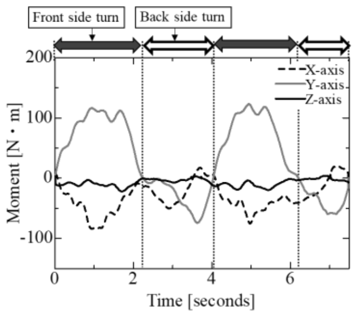
(a) Travel direction side (left) force.



(b) Travel direction side (left) moment.

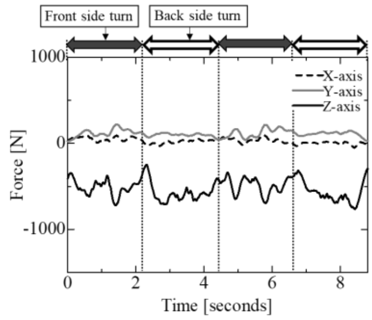


(c) Counter travel direction side (right) force.

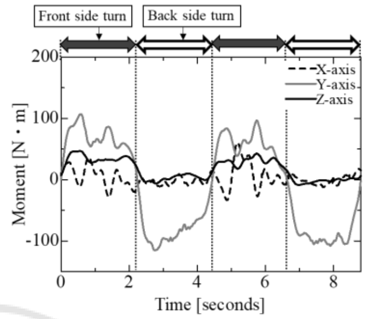


(d) Counter travel direction side (right) moment.

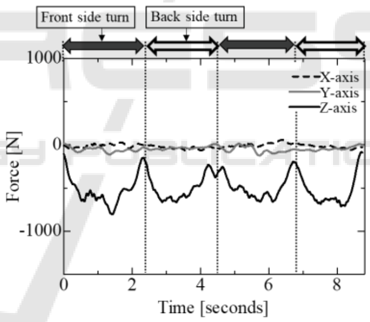
Figure 9: Reaction force from the snow surface of snowboard turns in alpine snowboarding.



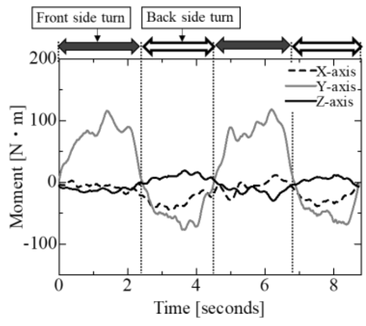
(a) Travel direction side (left) force.



(b) Travel direction side (left) moment.



(c) Counter travel direction side (right) force.



(d) Counter travel direction side (right) moment.

Figure 10: Reaction force from the snow surface of snowboard turns in freestyle snowboarding.

Table 1: Center of pressure in turns (X-axis coordinate).

Turn number		Travel direction side (left) foot Alpine	Travel direction side (left) foot Freestyle	Counter travel direction side (right) foot Alpine	Counter travel direction side (right) foot Freestyle
COP in front side turns	6th	65	139	113	113
(mm)	8th	77	145	104	120
COP in back side turns	7th	-98	-153	-74	-106
(mm)	9th	-96	-154	-88	-113

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