PLANTAR PRESSURE DISTRIBUTION ANALYSIS OF ALPINE AND BOARDER-CROSS SNOWBOARDERS' CARVING TURNS

Chong Hoon Lee[1], Jinho Back[2], Jusung Lee[2], Siddhartha Bikram Panday[2] and Young-Tae Lim [3]

[1]Department of Sports Science, Seoul National University of Science & Technology, Seoul, South Korea
[2]Kangwon National University, Samcheok City, South Korea
[3]Konkuk University, Chungju City, South Korea

Plantar pressure distribution analysis of alpine and boarder-cross snowboarders' carving turn was performed to provide instructors and snowboarders with scientific and quantitative data for evaluation of the turn. Snowboarders from Korean National Team for 2018 Pyeongchang Winter Olympics were chosen as subjects. To allow on-snow measurements of plantar pressure distribution, the boots were outfitted with pressure sensitive insoles. The carving turn section was divided into 5 events and 4 phases of which force, maximum pressure, and plantar contact area were analyzed. Comprehensive kinematical analysis was conducted which indicated the major features of pressure distribution in two different sporting events. The proposed results can be used as a reference for improvement of the training method in snowboarding.

KEY WORDS: pressure insoles, Winter Olympics, snowboarding, carving turn, plantar contact area.

INTRODUCTION: "Snowboarding" a popular winter sporting can be mainly be categorized into 3 categories according to their riding characteristics which Freestyle, Alpine, Boarder cross (Platzer, et al., 2009). Different types of boards are used in different events. Among them, Alpine boards are used for downhill speed racing, rotation, and carving turns. Moreover similar to alpine skiing, alpine snowboarding requires proper posture in order to decrease the air resistance and depending on the topography of the slope effective jumping skills are needed in order to avoid losing speed. Whereas, "Boarder-cross snowboarding" is a mix between speedy alpine snowboarding event and freestyle where similar to freestyle ski event, a group of 4~6 snowboarders start simultaneously performing rotations, jumps through the inclined course full of obstacles and race to reach the finish line first. Hence, turn plays an important part in these two events, where a technically effective turn plays an important role to link and execute another turn thus decreasing the elapsed time.
Especially, carving turn is one of the advance techniques in snowboarding where snowboarder boards by applying pressure and shifts the weight to the edge of the board through inclination to perform a smooth clean turn. The technical phase of a snowboard turn starts from the traverse up and un-weighting the pressure down through the fall line. Different stances and balance are used for various centring situation. Steering, rotation, pivoting are used to change the direction of the board; edging and turns can be achieved by combination of inclination and angulation (CASI, 2000) (Jo Hyun-dae, 2011). Both skiing and snowboarding requires similar basic turn principles with up-down movements as well as requires tilting to bear the centrifugal force and shows similar pattern of angulation for increasing the edge angle as in cycling.
Thus when performing a snowboard turn, the centre of mass shifts according to the motion of the lower limbs as well as characteristics of pressure applied on the foot varies which can be measured with the use of plantar pressure measurement system. Therefore, biomechanical analysis through plantar pressure measurement system is also one of area with a lot of attention in exercise science where it is being used to measure different daily activities or can even be used to observe special targeted functional activity of certain part of the foot (Roh Jung-suk et al., 2001). In addition, plantar pressure measurement system is also needed to analyze the dynamic plantar load distribution of normal and abnormal foot in biomechanics. Moreover, variable such as the structure and movement of upper foot also influences the

dynamic load distribution in the sole of our feet (Alexander I.J, et al., 1990) (Han, Jin-Tae, et al., 2010). Therefore, equipments for analyzing the plantar foot pressure have been actively used in different researches. Data such as peak pressure, mean pressure, maximum force and contact area as well as other variables can be obtained through plantar foot pressure measurement system (Park Seung-Bum, et al., 2007). Researches related to snowboard turn and pressure distribution (Kiyoshi Hirose, et al., 2012) (Thomas Holleczek, et al., 2009) have pointed out the importance of use of these equipment which can be used for testing and developing new equipment as well as training methodology. However domestic researches in the field of kinematical analysis as well as plantar pressure distribution of snowboard turn rarely exists.

In this respect, the aim of our research is to perform plantar pressure distribution analysis as well as identify the characteristics of the motion in a carving turn in alpine and boarder-cross snowboarder. Moreover, the study aims on providing scientific data to snowboarders and winter sports instructor which can be used to evaluate and to enhance the performance.

METHODS: Two snowboarders (1 Alpine; age: 19 yrs, height: 174 cm, weight: 64 kg) (1 Boarder-Cross; age: 19yrs, height: 174 cm, weight: 76 kg) from Korean National Team for 2018 Pyeongchang Winter Olympics participated in the study. All subjects were allowed to use their own boots. The boots were outfitted with pressure sensitive insoles (PEDAR mobile, Novel GmbH, Munich) for on-snow measurements of plantar pressure distribution. The insole pressure signal (99 cells per insole) was collected at 50 Hz and sent to a control unit, which the snowboarders wore on their backs Figure 1(a). The control unit was equipped with a memory card that allowed storage of the data. Before the field tests, all pressure insoles were recalibrated in the laboratory using the standard calibration manual from Novel. The experimental slope was 866m in length at an altitude of 238.7m with average pitch of 15.41°to maximum pitch of 36.0° in the advanced course. The distance between each gate was about 20m. Snowboarders used a webcam mounted on their helmet and 3 additional video cameras were also properly positioned on the slope which was used for documentation and identification of turn phases. The participants were allowed enough time to warm up and time to do two test run to familiarize with the slope conditions and to ensure actual competition condition. Prior to the test, the experimental procedures and possible risks were communicated verbally and in writing to all study participants, who then gave their informed written consent.

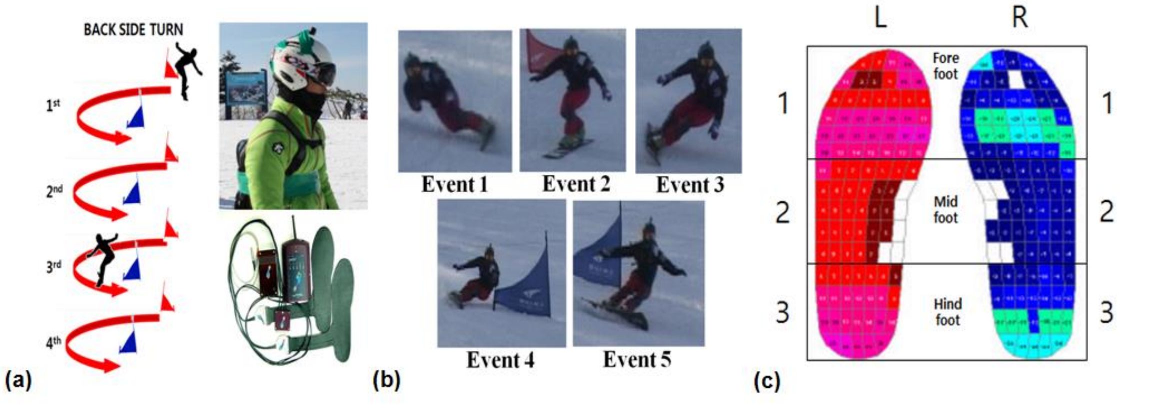

Figure 1: (a) Experimental Condition, (c) Classification of movement in different Events (E1 to E5), (b) Classification of Pressure Mask Regions in each foot which were subdivided into Left-forefoot (L1),Left-mid foot(L2),Left-hind foot(L3), Right-fore foot(R1),Right-mid foot(R2), Right-hind foot(R3).

The runs were divided into 5 Events (E1: starting point of extension (up), E2: complete contact point of deck to the ground surface, E3: point of complete flexion (down), E4: maximum angle of lean during back side turn, E5: starting point of next extension) and 4 Phases(P1: E1 to E2, P2: E2 to E3, P3: E3 to E4, P4:E4 to E5) of which four back carving turns were selected and their mean values were calculated for analysis Figure.1 (b). Furthermore, the pressure maps of each insole were divided into three regions: the forefoot, the mid foot, the hind foot. The data obtained was analysed using PEDAR-X software (PEDAR mobile expert version 7.3). Vertical force, maximum pressure, and plantar contact area were analysed in each foot and in each region defined by the masks. In addition, classification of pressure mask regions is presented in Figure 1 (c).

RESULTS AND DISCUSSION: The result data regarding force, maximum pressure, and plantar contact area were processed and are presented in Table 1. The mean value of force of alpine and boarder-cross snowboarders appeared highest in Left-hind foot (L3) in both snowboarders (Alpine: 479.14N, 471.75N, 554.29N, 551.58N; Boarder-cross: 405.79N, 490.64N, 581.21N, 487.36N). It is considered that higher pressure values were obtained due to the placement of left foot in front side while snowboarding. Moreover, it is considered that to control oneself in increasing speed, pressure was applied to Left-hind foot region due to which higher value were obtained.

Table 1. Plantar Pressure Distribution Analysis of Alpine and Boarder-Cross Snowboarders in Different Phases

		Alpine						Boarder-cross					
		L1	L2	L3	R1	R2	R3	L1	L2	L3	R1	R2	R3
Mean value of force (N)	P1	265.79	247.98	479.14	249.83	334.44	69.15	201.90	252.40	405.79	223.33	251.52	294.16
	P2	286.90	272.00	471.75	223.88	311.97	84.28	165.53	230.97	490.64	130.61	173.17	349.59
	P3	329.76	314.71	554.29	230.29	320.16	120.49	168.03	247.47	581.21	29.33	103.29	458.65
	P4	357.68	304.16	551.58	351.41	336.69	155.02	156.15	239.72	487.36	27.12	95.13	420.11
Maximum Pressure (kPa)	P1	238.97	124.50	301.25	145.94	175.68	38.72	128.13	98.59	149.53	132.34	143.91	116.25
	P2	258.63	135.17	341.46	133.33	178.40	41.21	108.75	82.29	174.17	90.42	97.92	138.75
	P3	302.38	157.13	448.44	128.13	208.23	52.13	109.69	81.25	206.88	40.63	41.88	181.56
	P4	403.75	145.50	239.38	140.00	217.08	61.75	103.13	74.38	177.50	46.88	43.13	166.25
Plantar Contact Area (cm^2)	P1	42.36	53.07	38.97	31.65	59.11	21.60	37.36	60.44	40.77	29.79	52.75	38.24
	P2	45.09	55.76	38.37	27.11	60.37	25.15	34.46	58.90	40.77	23.58	48.51	38.56
	P3	46.56	57.41	38.17	23.45	64.37	34.58	33.44	57.39	40.77	13.87	45.40	40.77
	P4	47.06	59.19	39.52	19.04	64.88	36.20	32.28	59.16	40.77	11.88	39.15	40.77

The mean value of force in boarder-cross snowboarder's Right-hind foot (R3) (294.16N, 349.59N, 458.65N, 420.11N) significantly appeared higher than alpine (69.15N, 84.28N, 120.49N, 155.02N). Hence, the result is considered due to differences in technical skill characteristics of alpine board than boarder-cross which made it prone to slips. The value of maximum pressure in each phase appeared higher in alpine in all regions than boarder-cross excluding Right-hind foot (R3). The result obtained is considered as characteristics of the alpine snowboarding which involves faster speed, thus demands pressure in order to cope with the increased velocity. However, higher value in Right-hind foot (R3) was obtained from boarder-cross which is due to positioning of stance in square style setting as well as due to boarder-cross boards which are more prone to slips.

The value of planter contact area generally appeared wider in both Right and Left-mid foot region (R2, L2) of alpine snowboarder in all phases. Whereas, smallest plantar contact area was in P1: 21.60 cm2, P2: 25.15cm2 of Right-hind foot (R3) and P3: 23.45 cm2, P4: 19.04 cm2 of Right-forefoot (R1). Value of planter contact area appeared the widest in Left-mid foot region (L2) whereas, Right-forefoot (R1) the smallest in boarder-cross. The difference in value of plantar contact area of two snowboarders is considered as a result of differences in binding setting. Lowest value of contact area is Right-forefoot (R1) is considered as a result of position of the right lower limb at the tail of the board which contributes much on controlling the board.

CONCLUSION: The study was conducted in order to analyse the in-boot pressure distribution in carving turn of alpine and boarder-cross snowboarder. Furthermore, the study aims to identify the characteristics of the snowboarder's motion in a carving turn and analyse the differences kinematically. Moreover, the study aims on providing scientific data to snowboarders and winter sports instructor which can be used to evaluate and to enhance the performance.

In conclusion, maximum pressure value appeared higher in alpine than boarder-cross snowboarder due to the characteristics of alpine snowboarding which involves faster speed and demands pressure in order to cope with the increased velocity. However, higher value in right-hind foot (R3) was obtained from boarder-cross which is considered due to positioning of stance setting in square style as well as the due to the feature of the boarder-cross deck which are usually more prone to skidding than alpine decks. It is also considered that when skidding appears in carving turn, frictional resistance largely appears between the board and snow surface due to which the turn cannot be executed through the radius of a turn or the radius of side cut. Eventually, the snowboarder should perform pivoting and rotation as well as apply strong edging through angulations which can reduce slipping and prevent frictional brake thus increasing the effectiveness of a turn.

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