

# Specific Fitness Profiles through Analysis of the Correlation between Anaerobic Power, Maximal Strength, and Isokinetic Strength in Korean National Snowboarders

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## Abstract

**Purpose:** We examined the associations between anaerobic power, maximal strength, and isokinetic strength in Korean National snowboarders.

**Methods:** We examined cross-sectional associations between isokinetic trunk strength in 89 Korean National snowboarders (mean age:  $22.17 \pm 4.82$  years). The main outcome measures were the Wingate anaerobic power test, maximal strength test, and isokinetic knee strength test.

**Results:** Isokinetic trunk strength was correlated with anaerobic power (lower average power, peak power, and power-drop rate). Further, trunk strength flexion and extension were significantly associated with maximal strength (knee strength and one-repetition maximum).

**Conclusions:** The Korean national snowboarders' anaerobic capacity and maximal muscle strength measurements were positively associated with their isokinetic trunk strength. Further research is needed to elucidate the core balance and muscle-growth mechanisms underlying this association; ideally, future studies will involve exercise and treatment interventions to identify causal relationships.

Key words: Korean national snowboarders, elite athletes, isokinetic muscle strength, anaerobic power

## Introduction

Snowboarding, which originated in the United States in the 1960s, has become one of the most popular winter sports. The International Olympic Committee officially

adopted snowboarding as an Olympic sport following the 1988 Nagano Olympics; it has since established itself as a core winter sport (Bladin, McCrory, & Pogorzelski, 2004). Snowboarding is an asymmetric sport where players place only their left or right leg on the board (Staniszewski, 2019). Olympic snowboarding involves three types of events: freestyle (SBFs), snowboard cross (SBX), and alpine (SBalp).

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Freestyle (SBFs) is a technique-based event where players perform tricks and jump on slopes using specially manufactured rails and half-pipe gravity structures. The snowboard cross (SBX) events take place on courses with various obstacles such as banks and jumps, requiring the distribution of players' body mass gravitating toward the center of the board. Finally, alpine (SBalp) is an event where the players must naturally keep their center mass toward their rear leg (RL), so that they can rotate easily and control their boards' direction and speed (Vernillo, Pisoni, Sconfienza, Thiebat, & Longo, 2017).

Elite snowboarders need highly developed muscle strength, aerobic ability, anaerobic power, balance, and coordination for the SBFs, SBX, and SBalp events (Hydren et al., 2013). World-class snowboarders have high (Platzer, Raschner, Patterson, & Lember, 2009) anaerobic capacity and strong lower bodies and cores (Gathercole, Stellingwerff, & Sporer, 2015; Losnegard, Myklebust, & Hallen, 2012; Sandbakk, Ettema, Leirdal, Jakobsen, & Holmberg, 2011; Zebrowska, Zyla, Kania, & Langfort, 2012). Their performance can also be affected by external factors that require them to adapt during the events. For example, because they must constantly adjust their boards' speed, movement, and direction, good balance is also critical (Vernillo, Pisoni, & Thiebat, 2018). Core muscles are particularly important because upper-body and posterior chain strength are critical, especially at the start of the events (Platzer et al., 2009). Multiple studies have shown that maintaining a good balance between muscle strength

and instantaneous muscle power is vital for keeping the body's center of gravity over the center of the board at high speeds, and good core muscle strength helps prevent lower-body injuries regardless of sex (Sporri, Kroll, Gilgien, & Muller, 2017). Nevertheless, further studies are needed that focus on the physical skills and training of elite snowboard athletes. To evaluate physiological factors, it is mandatory to evaluate the variables of physical strength relevant to each event. The data from such evaluations, along with monitoring of appropriate training methods, can serve as a fundamental basis for rehabilitation following injuries, and this will advance sports science, and improve snowboarders' performance (Platzer et al., 2009; Vernillo, Pisoni, & Thiebat, 2016; Vernillo et al., 2018). This study aimed to examine the relationship between Korean National snowboarders' upper- and lower-body anaerobic power, isokinetic knee strength, and maximal strength with their isokinetic trunk strength. This study's findings could help improve the performance of Korean National snowboarders athletes, and in planning effective and scientific training methods.

## Methodology

### Research Subjects

The subjects of this study were 89 male and female snowboarders from the Korean National team ( $22.17 \pm 4.82$  yrs.,  $170.19 \pm 16.17$  cm,  $74.61 \pm 11.01$  kg) whose physical characteristics and physical strengths have been measured regularly from 2013-2019. The physical

**Table 1.** Characteristics of study participants by group

Variable	Full Sample, n = 89	Male, n = 66 (74.2%)	Female, n = 23 (25.8%)	F Value	p Value
Age, y, mean (SD)	22.17 (4.82)	22.24 (5.10)	21.96 (4.02)	2.972	.088
Height, cm, mean (SD)	170.19 (16.17)	172.09 (18.60)	165.26 (3.39)	3.224	.076
Weight, kg, mean (SD)	74.61 (11.01)	77.41 (10.37)	66.57 (8.73)	1.644	.203
Body fat, %, mean (SD)	20.67 (7.24)	14.23 (3.72)	25.43 (5.22)	1.069	.308
Body Mass Index, kg/m <sup>2</sup> , mean (SD)	24.78 (2.39)	24.95 (2.24)	24.33 (2.75)	2.575	.112

Abbreviations: Values are mean and standard deviation.

characteristics of the subjects who participated in this study are shown in Table 1.

## Measuring Methods

**Body Composition.** For body composition, we measured the snowboarders' height (cm), body mass (kg), body fat percentage (% fat), weight with empty stomachs (kg), and body mass index ( $\text{kg}/\text{m}^2$ ) (Yoon et al., 2017) using bioelectrical impedance analysis and the InBody 720 multiple frequency bioelectrical impedance analysis device (Inbody Co., Ltd., Seoul, Korea).

**Anaerobic Power.** For anaerobic power, we measured the snowboarders' peak power (w/kg), mean power (w/kg), and power-drop rate (%) using a 30-second Wingate test with a Monark Model 824E flywheel ergometer (Monark Exercise AB, Vansbro, Sweden) and a Brachumera Sport arm ergometer (Lode BV, Groningen, The Netherlands). To measure the variable of anaerobic power, we defined peak power (w/kg) as the maximum value of the sectional record for five seconds in 30 seconds of exercise time during the evaluation and defined mean power (w/kg) as an average of the sum of the average value of each five seconds. The participants performed a warm-up exercise using the cycle ergometer for three minutes at 60 rpm and 100 w, and this was measured for 30 minutes, with the tension set at 7.5% (4.41 J) relative to the body weight. The evaluation after the warm-up exercise started with an oral signal ("start") following an oral count synchronized with a dial tone generated by a computer five seconds prior to the measurement (Kim, Song, & Min, 2016).

**Maximal Strength.** We measured the snowboarders' maximal strength with an ACE 2000 multifunction exerciser (Ariel Dynamics Inc., Trabuco Canyon, California, USA), capturing the maximal weight each person could lift with a bench press and squat. After ten minutes of warm-up with active stretching, the athletes performed 8–10 rep. at 40–60% of the strength of one-repetition maximum (1RM). We measured this

until the athletes could repeat the repetition with a weight increase of 5–10% for each set with a 3–5-minute break between sets (Grooten, Puttemans, & Larsson, 2002). The athletes were asked to stand upright, straighten their ankles and arms, grasp the handle of the measuring instrument, and bend their anterior scalene at about  $30^\circ$  to measure their back-muscle strength; this was done only once.

**Isokinetic Strength.** We measured the snowboarders' isokinetic strength using a Humac<sup>®</sup> Norm<sup>™</sup> isokinetic measuring device (Computer Sports Medicine Inc., Stoughton, Massachusetts, USA). We measured the snowboarders' knee-muscle strength at the angular velocity of  $60^\circ/\text{sec}$  and trunk strength at  $30^\circ/\text{sec}$ . First we measured the trunk strength followed by a sufficient break before measuring knee muscle strength. To measure their trunk strength, we adjusted the height of the foothold based on where the extension of the iliac crest on each athlete's waist met the spine. We firmly fixed the femur and placed the scapula pad in the center of the scapula. The athletes' upper bodies were completely fixed by connecting both linkages of the chest pads to the scapula pad. We asked them to grasp the handle in front of their chests with both hands. After we matched the driveshaft and the superior bone, we took the measurements while the athletes performed the actions of bending and elongating the waist joints, setting the operating range from  $0^\circ$  to  $90^\circ$  for elongation. To measure the athletes' knee-muscle strength, we asked them to sit in the measurement chair. Then, we adjusted the table and backrest until the center point of the knee joint matched the rotation axis of the dynamometer. To ensure that no external force was applied on body parts other than the knee joints during the flexion and extension actions, we adjusted for their leg length, and then fixed their thighs and torsos in place with straps. We set the range of operation from  $0^\circ$ – $90^\circ$  of the extension and toll measurements while they conducted flexion and extension actions for each load velocity. During the measurements, they performed warm-up exercises for the extension and flexion

movements three times to minimize any sense of unfamiliarity with or rejection of the equipment and maximize the performance. We calculated the peak torque (% BW) values after the athletes performed three flexion and extension actions with maximum force in both parts. We calculated the resulting values separately for the dominant and nondominant groups (Kim et al., 2016).

### Data Processing Methodology

We analyzed all the data gathered using the software Windows SPSS Statistics Version 23.0 (Armonk, New York, USA: IBM Corp.), using skewness and kurtosis to analyze the data and confirm its normal distribution. We calculated the athletes' body composition in mean (M) and standard deviation (SD). We conducted an independent t-test to examine the differences in body composition and professional body strength of male and female snowboarders. In addition, we used binary logistic regression to test the relationship among isokinetic strength, anaerobic power, and maximal strength. The statistical significance level was set at  $\alpha = 0.05$  for all items.

## Results

### Trunk Strength, Anaerobic Power, and Maximal Strength

The results of the logistic regression analysis performed to examine the relationship among national snowboarders' isokinetic trunk strength, anaerobic power, and maximal strength are shown in table 2. We separated the values into different three groups: males, females and total population. We found significant differences for both the males and the females in the flexor and extensor muscles in trunk strength of the lower body: (1) average power (flex/ex ratio total:  $\beta = .354, p = .006$ ; flexor muscle total:  $\beta = .761, p < .001$ ; extensor muscle total:  $\beta = .863, p < .001$ ); (2) peak power (flex/ex ratio total:  $\beta = .422, p = .001$ ; flexor muscle total:  $\beta = .659, p < .001$ , extensor muscle total:  $\beta = .835, p < .001$ ), and (3) power drop rate (flex/ex ratio total:  $\beta = .385, p = .003$ ; extensor muscle total:  $\beta = .345, p = .007$ ) in. However, we found no significant differences in the power-drop rate in the flexion muscles for either men or women. We found statistically

**Table 2.** Association Between Lower Anaerobic Power and Maximal Strength With Measures of Isokinetic Trunk Strength

	Anaerobic Power									Maximal Strength								
	Average power: lower (W)			Peak power: lower (W)			Power drop rate: lower (%)			Bench press (kg)			Squat (kg)			Back strength (kg)		
	$\beta$	R <sup>2</sup>	P	$\beta$	R <sup>2</sup>	P	$\beta$	R <sup>2</sup>	P	$\beta$	R <sup>2</sup>	P	$\beta$	R <sup>2</sup>	P	$\beta$	R <sup>2</sup>	P
<b>Isokinetic Trunk Strength</b>																		
<b>Flex/Ex ratio (%)</b>																		
Male	-.138	.019	.373	-.253	.064	.097	-.196	.039	.201	-.041	.002	.782	-.088	.008	.562	-.326	.107	.027
Female	-.410	.168	.129	-.457	.209	.086	-.556	.309	.031	-.343	.118	.229	-.127	.016	.678	-.093	.009	.752
Total	-.354	.126	.006	-.422	.178	.001	-.385	.148	.003	-.254	0.64	.048	-.254	0.65	.052	-.399	.159	.002
<b>Flexion (Nm)</b>																		
Male	.657	.432	<.001	.510	.260	<.001	-.022	.000	.888	.639	.409	<.001	.597	.356	<.001	.505	.255	<.001
Female	-.031	.001	.914	-.112	.013	.691	-.270	.073	.330	-.268	.072	.354	-.382	.146	.197	-.103	.011	.726
Total	.761	.579	<.001	.659	.434	<.001	.122	.015	.357	.352	.124	.005	.649	.421	<.001	.652	.425	<.001
<b>Extension (Nm)</b>																		
Male	.740	.548	<.001	.713	.508	<.001	.164	.027	.286	.670	.449	<.001	.689	.475	<.001	.773	.598	<.001
Female	.707	.500	.003	.692	.478	.004	.692	.478	.004	.288	.083	.319	-.202	.041	.508	.042	.002	.887
Total	.863	.745	<.001	.835	.697	<.001	.345	.119	.007	.449	.201	<.001	.751	.564	<.001	.841	.707	<.001

Abbreviations:  $\beta$ , completely standardized regression coefficient.

W, watts; Nm, newton meter.

significant differences in the flexor muscle, extensor muscle, and the ratio between flexor and extensor muscles for trunk strength for bench press which was the maximal strength (flex/ex ratio total:  $\beta = .254, p = .048$ ; flexor muscle total:  $\beta = .352, p = .005$ ; extensor muscle total:  $\beta = .449, p < .001$ ); squat (flexor muscle total:  $\beta = .649, p < .001$ ; extensor muscle total:  $\beta = .751, p < .001$ ); and back strength (flex/ex ratio total:  $\beta = .399, p = .002$ ; flexor muscle total:  $\beta = .652, p < .001$ ; extensor muscle total:  $\beta = .841, p < .001$ ). However, for squat, there were no significant differences in the flex/ex ratio in either males or females.

### Trunk Strength and Isokinetic Strength

The results of logistic regression analysis performed to examine the relationship between national snowboarders' isokinetic trunk strength and lower body knee muscle strength are shown in table 3. We separated the values into three different groups: men, women, and the total population. For all the groups, we found significant differences in the total values for trunk

strength, lower-body (knee) isokinetic strength, dominant flexor muscle trunk strength, trunk flexor and extensor strength, and the ratio between knee flexor and extensor strength (flex/ex ratio total:  $\beta = .267, p = .038$ ; flexor muscle total:  $\beta = .717, p < .001$ ; extensor muscle total:  $\beta = .822, p < .001$ ); extensor muscle (flex/ex ratio total:  $\beta = .307, p = .016$ ; flexor muscle total:  $\beta = .571, p < .001$ ; and extensor muscle total:  $\beta = .724, p < .001$ ). We also found significant differences in the total values of the nondominant flexor muscle (flexor muscle total:  $\beta = .749, p < .001$ ; extensor muscle total:  $\beta = .834, p < .001$ ); and extensor muscle (flex/ex ratio total:  $\beta = .360, p = .004$ ; flexor muscle total:  $\beta = .569, p < .001$ ; and extensor muscle total:  $\beta = .776, p < .001$ ). However, no significant differences were shown in nondominant flexion PT in the nondominant for either males or females.

### Discussion

We regularly measured the body composition and strength of 89 athletes on the Korean National

**Table 3.** Association Between Isokinetic Knee strength With Measures of Isokinetic Trunk Strength.

	Isokinetic Knee strength (60°/sec)																		
	Dominant						Nondominant						Flex R/L ratio (%)			Ex R/L ratio (%)			
	Flexion PT (Nm)			Extension PT (Nm)			Flexion PT (Nm)			Extension PT (Nm)			$\beta$	R <sup>2</sup>	P	$\beta$	R <sup>2</sup>	P	
	$\beta$	R <sup>2</sup>	P	$\beta$	R <sup>2</sup>	P	$\beta$	R <sup>2</sup>	P	$\beta$	R <sup>2</sup>	P	$\beta$	R <sup>2</sup>	P	$\beta$	R <sup>2</sup>	P	
<b>Isokinetic Trunk Strength</b>																			
<b>Flex/Ex ratio (%)</b>																			
Male	-.142	.020	.348	-.215	.046	.152	-.106	.011	.475	-.257	.066	.078	.058	.003	.700	.208	.043	.170	
Female	.302	.091	.274	-.013	.000	.963	.436	.190	.104	-.224	.050	.422	-.329	.109	.231	.364	.133	.182	
Total	-.267	.071	.038	-.307	.094	.016	-.233	.054	.067	-.360	.130	.004	.080	.006	.539	.350	.123	.006	
<b>Flexion (Nm)</b>																			
Male	.581	.338	<.001	.413	.171	.004	.624	.390	<.001	.431	.186	.002	-.151	.023	.316	-.244	.060	.106	
Female	.530	.281	.042	.251	.063	.367	.555	.308	.032	.104	.011	.713	-.110	.012	.697	.048	.002	.865	
Total	.717	.514	<.001	.571	.326	<.001	.749	.561	<.001	.569	.324	<.001	-.260	.068	.043	-.327	.107	.011	
<b>Extension (Nm)</b>																			
Male	.730	.533	<.001	.623	.388	<.001	.747	.558	<.001	.709	.502	<.001	-.166	.027	.272	-.450	.202	.002	
Female	.114	.013	.686	.329	.108	.231	-.076	.006	.787	.534	.285	.040	.402	.162	.137	-.609	.371	.016	
Total	.822	.675	<.001	.724	.525	<.001	.834	.696	<.001	.776	.603	<.001	-.266	.071	.038	-.519	.270	.000	

Abbreviations:  $\beta$ , completely standardized regression coefficient. PT, peak torque; Nm, newton meter; Flex, Flexion; Ex, Extension.

snowboard team between 2013-2019 to examine the correlation between anaerobic power, maximal strength, and isokinetic strength. Our body composition analyses found no statistically significant difference in either male or female athletes in terms of age, height, body weight, body fat percentage, and BMI. Our findings on body composition aligned with Vernillo et al. (2016) study of elite Italian snowboarders, confirming the importance of competitive snowboarders achieving and maintaining optimal physical conditioning to prevent injuries and successfully navigate courses and perform in half-pipes in high-speed events.

We found statistically significant differences in our isokinetic comparisons between trunk strength (flexor and extensor muscle) with lower-body anaerobic power, flexor muscle, extensor muscle, and the ratio between flexor and extensor muscles, average power, peak power, and power-drop rate. However, we found no statistically significant differences among the male or female athletes in the ratio between the flexor and extensor muscles and the flexor muscles analyzed as continuous variables. There was no significant difference in the power-drop rates for the flexor muscles. Prior studies have reported that a lack of trunk strength and anaerobic power increases snowboarders' risk of injuries by limiting their performance capabilities, physical skills, and speed (Bakken, Bere, Bahr, Kristianslund, & Nordsletten, 2011; Torjussen & Bahr, 2005; Turnbull, Kilding, & Keogh, 2009). This implies lower-body muscle strength is essential to support the high load generated during snowboard maneuvers. Thus, the failure to properly develop lower-body anaerobic power and trunk muscle strength could negatively affect snowboarders' performance and have a high correlation with injuries. Most previous studies on snowboarders have focused on lower-body muscle strength rather than overall body strength of the body (Falda-Buscaiot & Hintzy, 2015; Wijdicks et al., 2014), although Gathercole et al. (2015) conducted a validity study on the effects of acute fatigue on training among elite Canadian SBX snowboarders. Additional

trunk-strength studies that subdivide the level of anaerobic power by sex and specific snowboard event could help coaches develop effective training methods for elite snowboarders.

We also found statistically significant differences in the athletes' upper and lower bodies and maximal back strength—specifically, the isokinetic trunk strength flexor muscles, extensor muscles, and the ratio between flexor and extensor muscles. However, we found no statistically significant differences for either the male or female snowboarders between the isokinetic trunk flexor–extensor ratios and the squat tests. In addition, we found statistically significant differences between the dominant and nondominant leg muscles for both the male and female snowboarders. In contrast, we found no statistically significant differences in the isokinetic trunk flexor–extensor ratios. This suggests that trunk and lower-body strength asymmetry could be used as predictive variables for snowboarding injuries (Impellizzeri, Rampinini, Maffiuletti, & Marcora, 2007). Vernillo et al. (2016) reported muscle-strength asymmetry between the FLs and RLs of elite SBalp snowboarders. Similarly, we found evidence of morphological asymmetry; all the snowboarders we tested had significant lower-body RL and FL muscle asymmetry. These results were reasonable because snowboarders need to distribute more weight over the RL. Vernillo et al. (2017) reported strength differences up to 14% before and after a SBalp race. Further studies are needed to determine whether functional and morphological muscle asymmetry in snowboarders is merely descriptive for the sport or could serve as a variable for injury prediction. However, this study shows that, at the minimum, muscle-strength asymmetry should be considered seriously concerning musculoskeletal injuries. Because there have been relatively few snowboarder-focused studies, there is an urgent need for research on predictive models that could improve snowboarders' performance and anticipate injuries. There is also a need for professional training plans to improve isokinetic trunk strength, lower-body

anaerobic power, and maximal strength.

This study had several limitations. First, we studied only elite national snowboarders. Second, our sample size was relatively small, meaning that the results might not be generalizable enough to support specific changes to training regimens. Third, we studied only Korean athletes; our results might have been different if we included all Olympic-level or elite snowboarders.

## Conclusion

We found that isokinetic trunk muscle strength, lower-body anaerobic power, and maximal strength were positively correlated. In particular, we found above-average lower-body anaerobic power in both male and female athletes. However, no consistent results were correlating lower-body maximal strength with elite female athletes. We found that overall maximal strength generally characterized the elite male snowboarders, but the results for the right-left flexor–extensor muscle ratios were inconsistent for the three types of female snowboarders. Thus, we concluded that trunk strength in the center, high-upper, and lower-body muscles, and anaerobic power were essential for elite snowboarders irrespective of sex or the type of snowboard event. The results of this could inform training programs for the Korea National snowboard teams and other elite snowboarders and provide a basis for further research in the field.

## Conflicts of Interest

The authors declare no conflict of interest.

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