



Role of physique and physical fitness in the balance of Korean national snowboard athletes

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ABSTRACT

Background: The objective of this study is to understand the relationship between physique, physical fitness, and balance performance for snowboard athletes.

Methods: We considered all Korean national snowboard athletes ($n = 9$ with 6 males and 3 females, age = 17.44 ± 4.42), who have an experience of competition at continental cup level, to measure their physique, physical fitness, and (both static and dynamic) balance. Static balance was evaluated based on one-legged standing, while dynamic balance was estimated using a stability platform.

Results: Static balance is strongly correlated ($p < 0.05$) with circumference of the left lower leg (34.49 ± 2.42 cm; $\rho = 0.68$), sit-up (57.56 ± 8.8 ; $\rho = 0.72$), sargent jump (50.22 ± 11.78 cm; $\rho = 0.67$), strength of bench press (39.11 ± 17.73 kg; $\rho = 0.67$), angle of left ankle dorsiflexion ($73.78 \pm 7.86^\circ$; $\rho = 0.77$), average extension strength at 180° for left knee (321 ± 63.95 %BW; $\rho = 0.77$) and right knee (337 ± 60.32 %BW; $\rho = 0.77$), and right knee peak flexion strength at 60° (148 ± 25.61 %BW; $\rho = 0.73$). Center dynamic balance is negatively correlated with circumference of the right lower leg (34.63 ± 2.38 cm; $\rho = -0.67$, $p < 0.05$), while right dynamic balance is positively correlated with left ankle flexion ($148.44 \pm 5.20^\circ$; $\rho = 0.78$, $p < 0.05$).

Conclusion: Static balance is related to core muscle endurance and power, ankle flexibility, and knee stability, while dynamic balance is negatively correlated with circumference of the most frequently used lower leg (i.e., the leg dominating the snowboarding stance). The relationship between physique, physical fitness, and balance provides an insight into improving the balance performance of elite snowboard athletes through a training program that can affect the physique and physical fitness factors related to balance.

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Introduction

The balance of athletes is one of the key factors in determining their performance and injury risk during a sporting event. For high-speed sports such as snowboarding and skiing, temporary loss of balance even for a short duration has a critical effect on the record and injury risk that can even threaten the life of athletes.¹ As snowboarders need to overcome the speed and centrifugal force acting on them during the course, there is a complex, inevitable interaction between their body and the environment during snowboarding.² For instance, the vestibular and somatosensory apparatus of snowboarders, as well as their visual response, has to

be activated for them to maintain center-of-mass while snowboarding. To resist an extrinsic force, snowboarders assume specific postures that require activation of core muscle and leg muscles. In particular, the core muscles (i.e., abdomen and spine muscles) are responsible for a stable posture, whereas the upper leg muscles allow the up-down stance, and the lower leg muscles serve as a lever for tilting (angulation) of snowboarding posture. One of the key parameters representing such an interaction between the body of snowboarders and environment is the balance.³ Here, balance can be defined in two ways – (i) *static balance* is defined as the ability to retain a particular posture with minimum movement, and (ii) *dynamic balance* is denoted as the ability to regain a stability over doing particular posture.⁴ Balance capability helps determine snowboarding performance and reduce the injury risks.^{5–9}

In addition to balance, the physical fitness and physique of athletes are also important factors in determining their sport

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performance.^{10–21} Physical fitness and physique are considered to predict athlete performance in other sports and to evaluate their potential while scouting.^{22–26} Though balance, physical fitness, and physique are important factors for predicting the performance of athletes in sports such as skiing,^{27,28} the correlation between these important factors has not been fully studied for snowboard athletes. So far, there are few studies reporting the comparison between physique and balance for snowboard and other sports. For instance, a previous study by Alonso et al.²⁹ reports the relationship between static balance and height for comfortable upright posture using both feet for normal people (who are physically active) and a ~10% contribution of height to static balance of normal people. Moreover, Tabrizi and coworkers³⁰ showed that weight is correlated with the dynamic balance of athletes in other sports such as soccer, handball, and futsal. A recent study by Vernillo et al.³¹ suggests that the balanced posture of snowboarding is related to the strength asymmetry between front and rear legs. In addition, a previous study by Hrysomalis³² suggested a comparison between the balance capabilities of athletes in other sports such as soccer, swimming, basketball, and gymnastics. A previous study by Platzer et al.³³ describes the comparison between physical characteristics of elite snowboard athletes and their performances.

As described earlier, most previous studies had focused on the comparison between the balance of athletes in other sports (or normal people) and their physique (e.g., height and weight). There are very few studies^{31,33} on the physique and balance performance of snowboard athletes. However, the effects of both physique and physical fitness on balance of elite snowboard athletes has remained elusive. In this work, we studied the role of physique and physical fitness on the balance of elite snowboarders.

Methods

Participants

We considered all Korean national snowboarders (i.e., six male and three female snowboarders). The Korean national snowboard athletes were selected based on record and experience in major competitions, such as continental cups. The participants had not experienced orthopedic injury during the last six months. To avoid fatigue of the participants during competitive and preparation periods, they participated the measurement experiments during off-season, particularly summer season. The measurements were carried out in a laboratory condition. All participants were informed of our research and measurement procedures, and agreed with our methodologies; written consent concerning the voluntary participation was obtained from each participant. Our experiments were conducted based on permission from the Institutional Research Board (IRB) under IRB No. 2018-07-009. The physical characteristics of participants are described in Table 1.

Table 1
Physical characteristics of test participants.

Category	Male (n = 6)	Female (n = 3)	Average
Age (years)	17.83 ± 4.67	16.67 ± 4.73	17.44 ± 4.42
Career (years)	6.83 ± 3.25	6.33 ± 3.51	6.67 ± 3.12
Height (cm)	171.12 ± 8.35	158.93 ± 5.27	167.06 ± 9.36
Weight (kg)	64.02 ± 11.99	52.47 ± 3.76	60.17 ± 11.26
Stance (style)	Regular ^a	Regular ^a	–
Discipline	Alpine (n = 3)	Alpine (n = 3)	–
	Free style (n = 3)		

^a Regular stance: standing position in which the left foot is forward and the right foot is behind.

Measurement

The physique parameters of snowboarders, such as fat mass, body fat percentage, BMI, muscle mass index, were measured. Moreover, we employed Martin tool³⁴ for anthropometry in measuring the length and circumference of thighs, biceps, legs, chest, and waist. The physical fitness parameters were evaluated using a digital grip dynamometer, goniometer, and ACE-200 multi-function, HUMAC NORM. The details of how to measure the physique and physical fitness parameters of elite snowboard athletes are presented in Supplementary Method (in Appendix A). Among physical fitness parameters, an isokinetic ratio (ISR) defined as the ratio of flexion to extension for the knee joint is related to knee joint stability, which protects an athlete from anterior cruciate ligament injuries.^{35,36} Joint stability (JS) is defined as the deviation of ISR from the value of 60%, i.e. JS = |60% – ISR|. Static balance was measured based on one legged standing,³⁷ while dynamic balance was estimated on a stability platform.³⁸ We measured the time duration for a participant to stay in the left, right, and center of the platform over 1 min. During the test, sufficient periods of rest were allowed for the participants to avoid unnecessary factors that might affect the test results. The details of balance measurements are provided in Supplementary Method (in Appendix A).

Statistical analysis

The mean and standard deviation for measured data were calculated using SPSS (ver. 19). We conducted Spearman's rank correlation analysis between physique, physical fitness, and balance based on a significant level being set to 0.05.

Results

We studied the correlation between physique, physical fitness, and balance for snowboarders. As we found that explosive muscular strength (i.e. standing long jump) and agility such as side-step did not play any role in balance, these data were excluded from the discussion ($p > 0.05$). Table 2 shows the mean and standard deviation of measured quantities for physique, physical fitness, and balance.

Static balance

Fig. 1 shows the correlation between static balance and other parameters such as dynamic balance, physique, and physical fitness. Static balance is related to the circumference of the left lower leg ($\rho = 0.68$, $p = 0.04$), sit-up ($\rho = 0.72$, $p = 0.02$), sargent jump ($\rho = 0.67$, $p = 0.04$), bench-press ($\rho = 0.67$, $p = 0.04$), left ankle-dorsiflexion ($\rho = 0.77$, $p = 0.02$), left knee average power for isokinetic extension at 180° ($\rho = 0.77$, $p = 0.02$) and right knee isokinetic peak muscle flexion strength at 60° ($\rho = 0.73$, $p = 0.03$). This result indicates that snowboarders are required to have core strength and power, chest strength, ankle flexibility, and knee joint stability to maintain the statically balanced postures. Here, static balance was not correlated with dynamic balance, which is consistent with the previous finding of Hrysomallis et al.³⁹ That previous study³⁹ considered single limb standing on a force platform for measuring static balance, while we measured time duration for evaluating static and dynamic balance. In addition, the dynamic balance posture tasks of our work is different from that of the previous study.³⁹ Moreover, we identified a relationship between sargent jump and static balance, which is congruent with a previous study by Atilgan et al.⁴⁰ reporting that jumping, such as on trampoline, has a positive effect on static balance capability.

Table 2
Measured values of physique, physical fitness, and balance.

Category		Mean	Standard Deviation	N
Physique (Circumference)	Right thigh (cm)	52.98	4.40	9
	Left thigh (cm)	52.16	4.24	9
	Right lower leg (cm)	34.63	2.38	9
	Left lower leg (cm)	34.49	2.42	9
Physical Fitness	Sit up (for 60 s)	57.56	8.8	9
	Ankle flexibility – right dorsiflexion (°)	68.67	5.15	9
	Ankle flexibility – right plantar flexion (°)	147.33	7.6	9
	Ankle flexibility – left dorsiflexion (°)	73.78	7.86	9
	Ankle flexibility – left plantar flexion (°)	148.44	5.20	9
	Isotonic strength bench-press (kg)	39.11	17.73	9
	Isotonic strength squats (kg)	105.89	35.37	9
	Isokinetic maximum strength ratio (flexion/extension ratio) at 60° - right knee joint	60.00	7.00	9
	Isokinetic maximum strength ratio (flexion/extension ratio) at 60° - left knee joint	54.89	8.85	9
	Joint stability – right knee	5.33	4.12	9
	Joint stability – left knee	8.44	5.25	9
	Balance	One-legged standing (sec)	48.68	27.14
Left dynamic balance ^a (sec)		25.49	9.52	9
Right dynamic balance ^a (sec)		4.88	4.12	9
Center dynamic balance ^a (sec)		29.63	11.13	9

^a Left (right, or center) dynamic balance was defined as the time, in which a participant stays in the left (right, or center) of the platform during 1-min measurement.

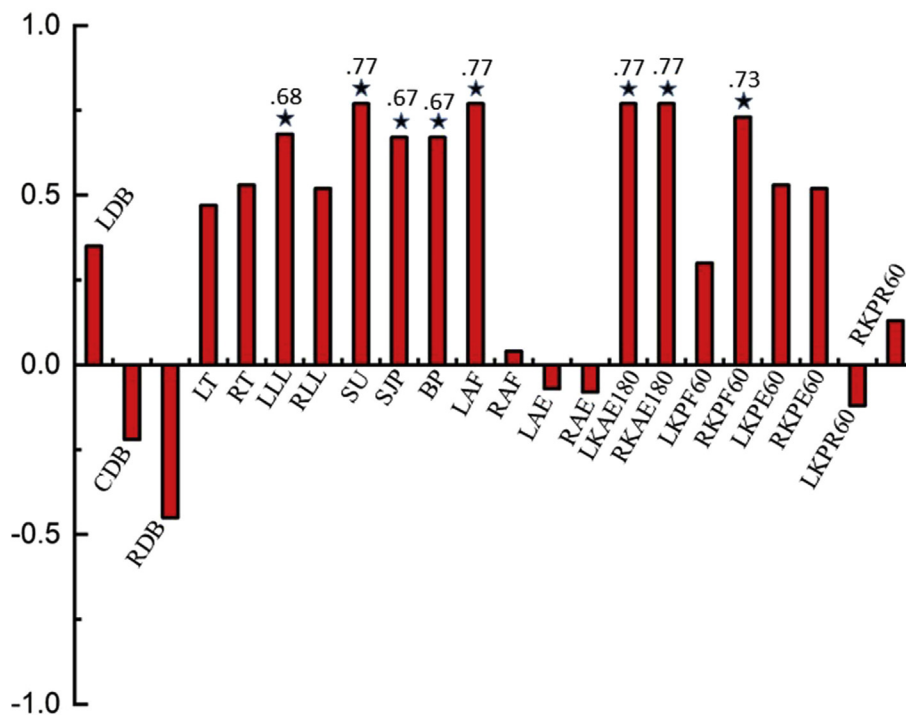


Fig. 1. Correlation of static balance with dynamic balance, physique, and physical fitness. Specifically, we considered the correlation of static balance with left dynamic balance (LDB), center dynamic balance (CDB), right dynamic balance (RDB), left thigh (LT), right thigh (RT), left lower leg (LLL), right lower leg (RLL), sit-up (SU), sargent jump (SJP), strength of bench press (BP), left ankle flexion angle (LAF), right ankle flexion angle (RAF), left ankle extension angle (LAE), right ankle extension angle (RAE), left and right average extension strength at 180° (LKAE180 and RKAE180), left and right knee peak flexion strength at 60° (LKPF60 and RKPF60), left and right knee peak extension strength at 60° (LKPE60 and RKPE60), and left and right knee peak flexion/extension strength ratio at 60° (LKPR60 and RKPR60). Here, blue stars indicate $p < 0.05$, and a red star represents $p < 0.01$.

Dynamic balance

Fig. 2a illustrates that left dynamic balance (LDB) is negatively correlated with center dynamic balance (CDB) ($\rho = -0.80, p < 0.001$) and left ankle dorsiflexion ($\rho = -0.70, p = 0.04$). However, LDB is positively correlated with left and right knee average power of isokinetic extension at 180° ($\rho = 0.68$ for left and $\rho = 0.67$ for right with $p = 0.04$ for both), left and right knee isokinetic peak muscle extension strength at 60° ($\rho = 0.82, p = 0.001$ for left and $\rho = 0.68, p = 0.04$ for right), and right knee isokinetic peak muscle

flexion strength at 60° ($\rho = 0.72, p = 0.03$). Fig. 2b shows that CDB is negatively correlated with circumference of the right lower leg ($\rho = -0.67, p = 0.04$), left knee isokinetic peak muscle flexion/extension strength at 60° ($\rho = -0.72, p = 0.03$ for flexion and $\rho = -0.68, p = 0.04$ for extension), and right knee isokinetic peak muscle extension at 60° ($\rho = -0.77, p = 0.02$). Fig. 2c describes that RDB has positive correlation with left ankle plantar flexion ($\rho = 0.78, p = 0.01$) and negative correlation with right knee isokinetic peak ratio at 60° ($\rho = -0.70, p = 0.04$). CDB is highly negatively correlated with LDB but not correlated with RDB. In

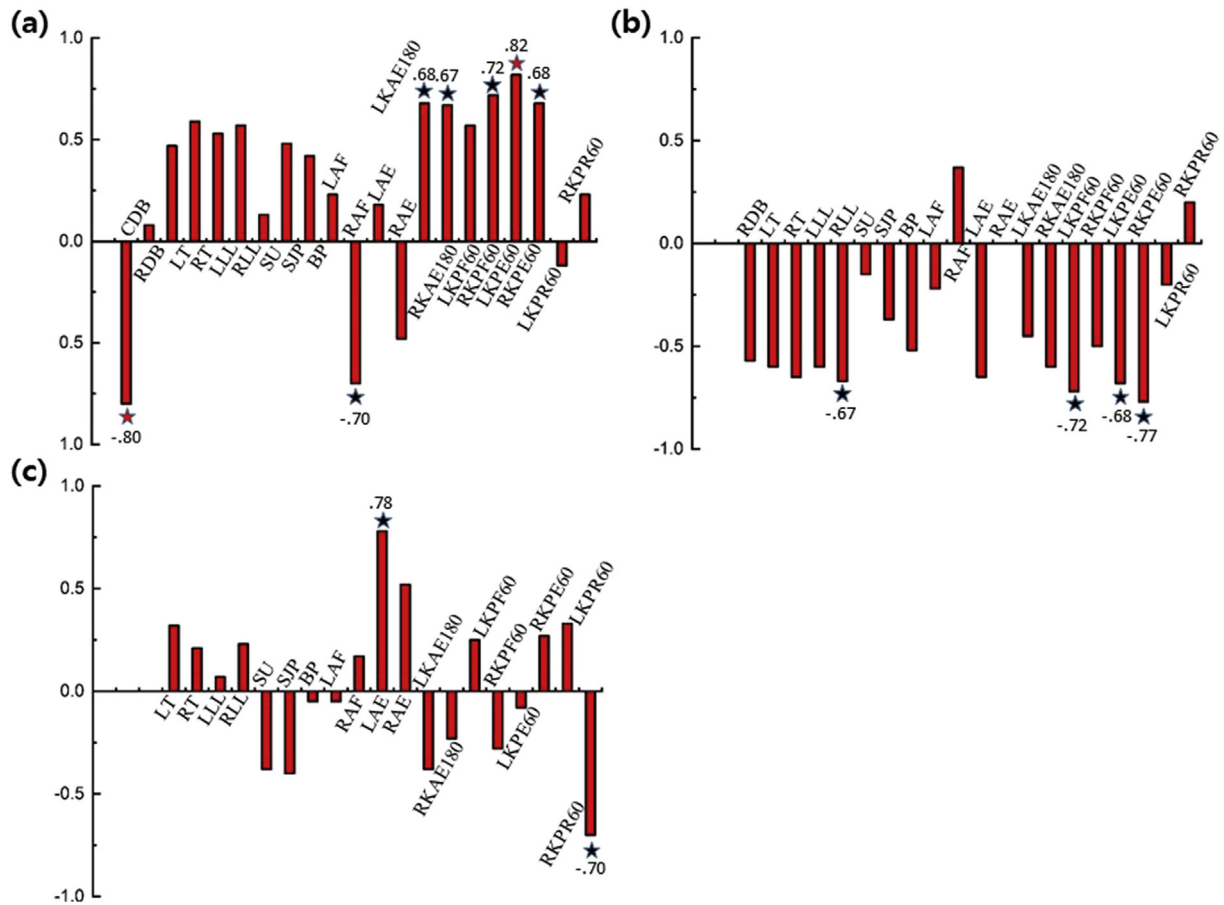


Fig. 2. Correlation of (a) LDB, (b) CDB, or (c) RDB with other parameters whose abbreviations were described in the caption of Fig. 1.

addition, Table 2 shows that the time duration for CDB ($t_c = 29.63 \pm 11.13$ s) is comparable to that for LDB ($t_l = 25.49 \pm 9.52$ s), while the time duration for RDB is much shorter ($t_r = 4.88 \pm 4.12$ s) (for each participant, see Fig. 3). This finding suggests that, when the posture of snowboarders is tilted to their right, they are able to immediately regain their stability.

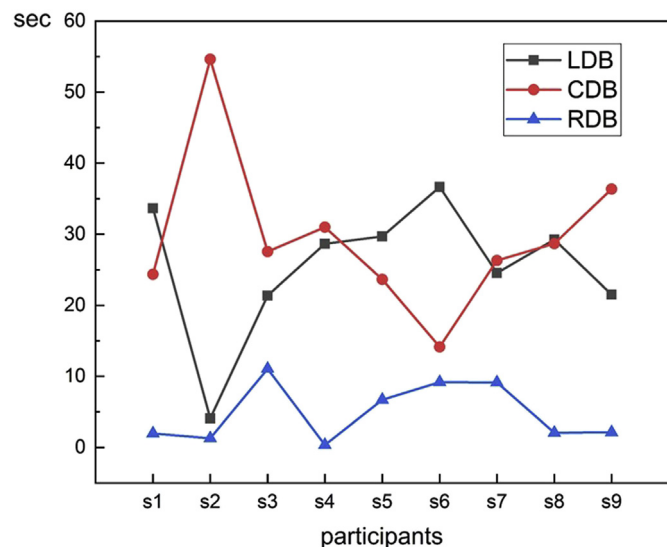


Fig. 3. Measured values of LDB, RDB, and CDB for each participant.

However, when their posture is tilted to the left, the snowboarders are not able to quickly regain stability. This is consistent with the fact that participants used a habitual, regular stance when attempting to maintain their balance. Moreover, as shown in Fig. 2b, CDB is negatively correlated with circumference of the right lower leg ($\rho = -0.67, p = 0.04$). This suggests that a decrease in circumference of the right lower leg results in better dynamic balance. Fig. 2c demonstrates that RDB is positively correlated with left ankle plantar flexion ($\rho = 0.78, p = 0.01$). This suggests that when snowboarders tilt to their right side, they are able to recover balance by increasing left ankle plantar flexion.

Discussion

We found a strong correlation of static balance with circumference of the left lower leg, sit-up, sargent jump, strength of bench press, angle of left ankle dorsiflexion, average extension strength at 180°, and right knee peak flexion strength at 60°, whereas center dynamic balance was negatively correlated with circumference of the right lower leg. The implications of these findings are discussed here.

Role of physique and physical fitness in static balance

As static balance was correlated with circumference of the left lower leg, the volume of the lower leg muscles (anterior tibialis, soleus, and gastrocnemius) may play a crucial role in static balance, and activation of those muscles may help fasten the left ankle for one-legged standing posture. The relationship between isotonic

strength bench-press and static balance suggests that, for maintaining the static balance, the stability of the upper body is essential and can be improved by isotonic strength exercise such as bench press. As a regular stance (i.e., left foot forward and right foot backward) was used to measure left ankle dorsiflexion and right knee joint extension stability, the strong correlation between static balance and right knee joint stability implies that the left and right legs were used in one-legged standing and were controlling balance while snowboarding. For the stability of the right leg, knee joint extension and flexion are also required. Maintaining knee stability by bending the left ankle of the lifted leg may help snowboarders maintain their static balance posture. Moreover, the effect of right knee isokinetic peak muscle flexion strength at 60° in static balance is consistent with a previous finding⁴¹ that, as right knee isokinetic peak muscle flexion strength at 60° (for hamstring) increases, so does static balance.

Effect of physique and physical fitness in dynamic balance

The correlation between RDB and left ankle plantar flexion suggests that the left ankle plays a role in dynamic balance posture and in steering a snowboard riding. The easier recovery of balance when tilted to the right side suggests that snowboarders use the left ankle for steering and the right leg to control dynamic balance. This is attributed to the ability of the right leg to sensitively control the board movement, because the somatosensory and muscle activation of the right leg are more sensitive than those of the left leg. This implies a specific balance somatosensory system related to the snowboard stance. Different sport type-associated motion techniques require the different types of balance.⁴²

The negative correlation between CDB and circumference of the right lower leg supports that increasing the girth of each body part leads to the difficulty of dynamic balance. Blaszczyk et al.⁴³ reported that the needless increase of weight may result in discomfort and restriction for maintaining balance in a kinematic aspect. This suggests that the dynamic balance of snowboarders can be improved by increasing muscle density and decreasing lower leg circumference. Our results do not show any role of weight and height in balance performance, in contrast to a few previous studies.^{29,30} In particular, Alonso et al.²⁹ found that height contributes to ~10% of static balance based on a regression analysis of 100 participants. Moreover, Tabrizi et al.³⁰ showed the significant positive effect of weight and height in static balance and dynamic balance by considering 50 healthy athletes.

Role of asymmetry for physique and physical fitness in balance

Due to postural asymmetry between left and right legs during snowboarding, we studied the effect of asymmetry of physique and physical fitness in static and/or dynamic balance. The left/right difference (i.e. asymmetry) in most physique and physical fitness parameters are not statistically correlated with the balance (Fig. 4). However, static balance was found to be negatively correlated with the left/right difference of knee flexion isokinetic strength at 60°. Less asymmetry of knee flexion isokinetic strength results in better static balance. Moreover, LDB is negatively correlated with the left/right difference of thigh circumference, while RDB is positively correlated with asymmetry of knee flexion peak isokinetic strength at 60°, which affects the right-slanted posture of snowboarders. Specifically, the snowboarders that tilted to their right side are more likely to be able to maintain dynamic balance if asymmetry of knee flexion peak isokinetic strength decreases. Here, it should be noted that snowboarders participating in this study used their right leg with placing more weight than their left leg (in a regular stance), and that the right thigh circumference is larger than that of

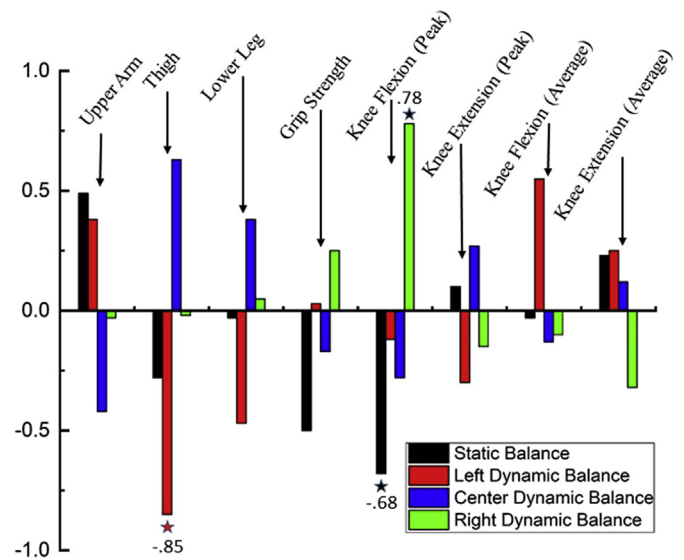


Fig. 4. Correlation between balance and asymmetry of physique and physical fitness.

left thigh. This study suggests that training of the left leg will be beneficial for improving dynamic balance, because asymmetry of the lower limbs may help prevent snowboarders from injury. It is consistent with a previous finding³¹ that the power asymmetry between front (i.e., left) and rear (i.e., right) legs affects snowboarding posture, which governs dynamic balance.

Biomechanical mechanism underlying the relationship between physique or physical fitness and balance

Our finding of the relationship between physique or physical fitness and balance provides biomechanical implications on snowboarding performances. During snowboarding, the athletes should maintain a stable posture, which indicates the important role of static balance. Based on the relationship result, for snowboard athletes to maintain a stable posture in a regular stance, their upper body should be in a stable position. In particular, the roles of core endurance and bench press in the static balance imply that the core abdomen muscles have to be activated with paraspinal muscles for antagonism, and that strengthening the chest would stimulate and enhance the trunk stabilizer muscles. In addition, the effect of ankle flexibility in static balance suggests that the ankle strategy is useful for maintaining a stable snowboarding posture. That is, the ankle strategy may allow for maintaining static balance during angulation and steering.^{44,45} The relationship between knee strength (or power) and static balance implies that strengthening the muscles around the knee is necessary to not only reduce the injury risk, but also improve the balanced snowboarding posture. On the other hand, strengthening upper body does not play any role in the dynamic balance that is required for turning when snowboarding. As the lower leg and knee are related to dynamic balance, the turning techniques of snowboard athletes can be improved by strengthening the knee and lower leg. Specifically, the strengthening of muscles in the right lower leg while reducing fat content (leading to a decrease in lower leg circumference) may enable snowboard athletes to perform swift, stable turns. For a turn, the right lower leg serves as a steering lever. For effective steering using the right lower leg, unnecessary mass (i.e. fat mass) of the right lower leg has to be reduced. In summary, the relationship between physique, physical fitness, and balance implies the important biomechanical mechanisms of snowboarding postures for improving snowboarding performances.

Limitations and applications

In this work, the relationship between physique or physical fitness and balance performances is found for elite snowboard athletes, who have experienced a continental cup-level competition. This relationship may provide insight into how to develop an effective training program to improve balance performance. Although we considered all Korean national snowboard athletes, the number is nine, which is too small to generalize our findings. We note that in Korea there are very few snowboard athletes whose level is comparable to that of national snowboard athletes. Moreover, quantitative analyses were used in this study, while the multi-method approach⁴⁶ based on both quantitative and qualitative analyses can be used for future studies. Despite the small sample size for our quantitative analyses, our study may provide guideline and/or future directions for further studies regarding the balance performances of snowboard athletes. For example, the effect of physical training on balance performance can be quantitatively characterized by measuring the relationship between physique, physical fitness, and balance. In addition, our study can be further extended to study the balance performances of snowboard athletes with respect to their experience and capabilities. Specifically, the comparative studies of the physique–physical fitness–balance relationship based on professional and amateur snowboard athletes (with different levels) will enable ideas of how to improve balance performance by designing a training program that aims to change critical physique and physical fitness factors related to balance performance.

Conclusion

In this study, we showed that the static balance of snowboard athletes is correlated with their core muscle endurance and power, ankle flexibility, and muscle strength of lower extremities. The dynamic balance increases by decreasing the circumference of right lower leg, which is frequently used in a regular stance. The relationship between physique or physical fitness and balance for elite snowboard athletes may allow development of a training program aimed towards improving balance performance. Specifically, a training program can be developed to strengthen the upper body (for stable posture) and the lower leg (for turning performance). In addition, the relationship may enable one to evaluate the effectiveness of training program by measuring the relationship during the training period.

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Declaration of competing interest

The authors declared no conflict of interest.

Author statement

Y.J. and K.E. designed the research. Y.J. performed experiments. Y.J. and K.E. analyzed the data and wrote the manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jesf.2020.07.001>.

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