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Original Article

The Role of Muscle Strength and Balance in Preventing Injury Risk Among Beginner Skiers

Atilla Çakar[1ABE] Nilufar Haydarova[2CDE*]

[1]*Kyrgyz-Turkish Manas University, Faculty of Sport sciences, ORCID: 0000-0002-3564-3909, atilla.cakar@manas.edu.kg, Kyrgyzstan*

[2]*Kyrgyz-Turkish Manas University, Faculty of Sport sciences, ORCID: 0009-0003-3798-5392, 2452Y2101001@manas.edu.kg, Kyrgyzstan*

**Corresponding author: 2452Y2101001@manas.edu.kg*

Authors' Contribution: A: Study design, B: Data collection, C: Data analysis, D: Manuscript preparation, E: Discussion and conclusion

ABSTRACT

Study aim(s): The aim of this study is to examine the relationship between back and leg muscle strength, balance parameters, and the number of falls among individuals participating in beginner-level alpine skiing training. Specifically, it evaluates how lower extremity and back strength, along with static balance ability, influence the occurrence of falls during skiing. Since falls may serve as a potential precursor to injuries in high-risk sports such as skiing, the study also explores the role of physical fitness in preventing these incidents.

Methods: A total of 23 volunteer participants (10 females and 13 males) undergoing alpine skiing training were included in the study. Participants' age, height, body weight, and BMI were recorded. Muscle strength was measured isometrically using back and leg dynamometers, while balance ability was assessed using the Flamingo Balance Test. Fall data were classified by coach observation during the training period into three descent-related falls, other falls, and total number of falls. Data were analyzed using IBM SPSS 26.0 software, and relationships between variables were examined using Pearson's correlation analysis.

Results: The highest number of falls occurred during downhill training. Leg strength showed moderate negative correlations with descent-related falls ($r = –0.40$, $p = 0.034$) and total falls ($r = –0.42$, $p = 0.031$), indicating that greater lower-limb strength was associated with fewer falls. Back strength was negatively correlated with all fall types ($r = –0.27$ to $–0.37$), although these relationships were not statistically significant ($p > 0.05$). Balance performance showed moderate positive correlations with descent-related ($r = 0.518$, $p = 0.011$), other ($r = 0.454$, $p = 0.029$), and total falls ($r = 0.556$, $p = 0.006$), suggesting that poorer balance ability was linked to a higher frequency of falls.

Conclusions: The findings indicate that muscle strength and balance capacity significantly affect the frequency of falls among novice skiers. As falls are potential precursor to injuries in high-risk sports like skiing, these results underscore the importance of physical fitness components in fall prevention. Therefore, systematically incorporating strength- and balance-focused training into ski education programs may serve as an effective strategy to reduce injury risk and enhance athlete safety.

Keywords: Ski Training, Sports Injury, Isometric Muscle Strength, Balance Performance

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INTRODUCTION

It is widely accepted in the sports science literature that sports injuries occur when the body is exposed to forces exceeding the physiological limits of its tissues, resulting in structural damage or functional impairment [1]. Alpine skiing, a prominent winter sport, is a technically demanding discipline that requires high levels of physical fitness, muscular strength, coordination, and balance. In particular, the strength of lower extremity muscles and the stabilizing function of core muscles play a critical role not only in skiing performance but also in ensuring safety on the slopes [2,3]. For beginner-level skiers, these physical attributes are essential not only for improving performance but also for preventing fall-related injuries [4].

Balance is defined as the ability to control the body's center of mass over its base of support, and it plays a vital role in both performance and safety, especially in dynamic sports such as skiing [5]. The unique balance demands of skiing stem from the necessity to maintain postural stability during high-speed turns and descents on variable snow and terrain conditions. Single leg static balance tests are commonly used to assess postural control in [6].

Previous studies have reported significant improvements in balance parameters following skiing and snowboarding training, with these gains being more pronounced at the beginner level [7,8]. Furthermore, it has been emphasized that increased strength in both lower and upper body muscle groups contributes to improved postural control, thereby enhancing static balance skills and significantly reducing the frequency of falls [9]. According to the literature, the vast majority (80–90%) of injuries in alpine skiing result from self-induced falls [10]. Therefore, systematic training programs aimed at developing both muscular strength and balance are essential for minimizing fall risk. Indeed, long-term training interventions in various sports disciplines have been shown to positively affect muscle strength, anaerobic capacity, and body composition [11]. Increasing strength in key areas such as the back and legs facilitates better balance during skiing, improves stability during turns, and enables quick postural adjustments when necessary [3,6].

This study aims to investigate the relationship between back and leg muscle strength, as well as static balance performance, and the frequency of falls among beginner-level participants enrolled in a ski training program. Considering that falls may constitute a significant risk factor for sports injuries in high-risk sports such as skiing, the findings of this study are expected to contribute to the restructuring of ski training programs with a focus on strength development, balance improvement, and injury prevention.

METHODS

Research design

This study was conducted using a single-group experimental design. Participants underwent short-term (weekly) ski training, during which measurements of strength, balance, and fall frequency were collected. The primary objective was to examine the relationship between back and leg strength, balance performance, and the number of falls. This research was conducted in accordance with the principles of the Declaration of Helsinki.

Participants

During the 2024–2025 academic year, a total of 23 volunteer participants from the Kyrgyz-Turkish Manas University Alpine Ski Team took part in this study. Of the participants, 10 were female with a mean age of 22.40 ± 0.70 years, and 13 were male with a mean age of 22.77 ± 1.01 years. All participants were receiving beginner-level alpine skiing instruction and had no prior skiing experience. Ski training sessions

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and fall observations were conducted at a ski training facility located in Bishkek, Kyrgyzstan, while strength and balance assessments were performed in the Performance Laboratory of the Faculty of Sport Sciences at Kyrgyz-Turkish Manas University.

Data collections tools and Measurements

Flamingo Balance Test:

To assess participants' static balance ability, the Flamingo Balance Test was administered. During the test, individuals were instructed to stand on one leg in a fixed position, and performance was scored based on time and the number of falls. Better balance was indicated by fewer losses of balance and the ability to maintain position for a longer duration [12].

Back Strength Measurement:

The isometric strength of the back extensor muscles was measured using a digital back dynamometer. Participants stood upright, bent forward without flexing their knees, and pulled with maximal effort. The highest recorded value was used in the analysis [3].

Leg Strength Measurement:

The isometric strength of the lower extremity muscle groups was assessed using a leg dynamometer based on similar principles. Participants exerted maximum force from a fixed position, and the highest value was recorded for analysis.

Fall Frequency:

All fall incidents during the ski training were recorded through coach observations and categorized as downhill falls, other types of falls, and total number of falls.

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics version 25. Descriptive statistics (mean, standard deviation, minimum, and maximum) were calculated for all variables (Tables 1 and 3). The normality of data distribution was tested using the Shapiro–Wilk test. For variables showing a normal distribution (back and leg strength), independent samples t-tests were applied to compare groups, and statistical significance was set at $p < 0.05$ (Table 2). Relationships among variables were analyzed using the Pearson correlation coefficient (r) (Table 4), with $p < 0.05$ considered statistically significant.

RESULTS

Table 1. Demographic Characteristics of Participants (Female: 10; Male: 13)

Variable	Gender	X̄±SD	Min	Max	T test (sig)
Height (cm)	Female	163.70 ± 3.33	160.00	170.00	0.000*
	Male	173.54 ± 5.85	165.00	182.00	
Body Weight (kg)	Female	66.80 ± 10.49	54.00	90.00	0.106
	Male	75.46 ± 14.13	58.00	109.00	
(BMI) (kg/m²)	Female	25.36 ± 3.53	21.19	33.87	0.827
	Male	25.01 ± 4.21	20.31	36.42	

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Female and male participants were within a similar age range, while height and body weight values reflected the expected physiological differences between sexes. The mean BMI values were comparable across both groups and generally remained within normal limits.

Table 2. Isometric Strength Values by Region

Variable	Gender	X̄±SD	Min	Max	T test (Sig)
Back Strength (kg)	Female	101.50 ± 18.42	85.00	140	0.003*
	Male	145.40 ± 27.72	100.00	200	
Leg Strength (kg)	Female	103.50 ± 40.48	50.00	170	0.028*
	Male	138.50 ± 27.45	100.00	180	

Male participants' back and leg strength values were found to be statistically significantly higher than those of female participants. This difference reflects sex-specific physiological characteristics, such as greater muscle mass and force production capacity in males.

Table 3. Descriptive Statistics for Types and Frequency of Falls Among Skiers

Variable	X̄±SD	Min	Max
Falls During Downhill Skiing	3.43 ± 0.77	1	5
Other Falls During Skiing Activities	2.13 ± 0.94	0	4
Total Number of Falls During Skiing	5.57 ± 1.62	1	8

Findings from the participants' fall data indicate that the highest number of falls occurred during downhill skiing sessions. The mean number of falls during descents was 3.43 ± 0.77, which was notably higher than the average of 2.13 ± 0.94 recorded for other skiing activities. The total number of falls averaged 5.57 ± 1.62. These results suggest that individual differences in balance control and muscular strength may influence the tendency to fall among novice skiers.

Table 4. Relationships Between Muscular Strength, Balance, and Fall Incidence

Parameter	sig	Downhill Falls	Other Falls	Total Falls
Leg Strength	r	-0.40	-0.35	-0.42
	p	0.034*	0.123	0.031*
Back Strength	r	-0.359	-0.271	-0.367
	p	0.092	0.208	0.085
Flamingo Balance	r	0.518	0.454	0.556
	p	0.011*	0.029*	0.006*

According to the correlation analysis, leg strength showed weak-to-moderate negative correlations with the number of falls ($p < 0.05$). Back strength demonstrated negative but non-significant associations with fall counts. In contrast, Flamingo Balance Test scores showed moderate positive and significant correlations with the number of falls ($p < 0.05$), indicating that participants with poorer balance

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tended to fall more frequently, as higher Flamingo scores indicate worse balance performance.

DISCUSSION

This study aimed to investigate the effects of back and leg strength, as well as balance ability, on the frequency of falls among beginner-level individuals undergoing ski training. The findings revealed that both muscular strength and balance parameters were moderately associated with the incidence of falls.

As presented in Table 1, the mean height of female participants was 163.70±3.33 cm, while that of males was 173.54±5.85 cm, representing a statistically significant difference (p =0.000). Mean body weight values were 66.80±10.49 kg for females and 75.46±14.13 kg for males, with no significant difference between groups (p = 0.106). Similarly, the mean BMI values were 25.36±3.53 kg/m² for females and 25.01±4.21 kg/m² for males (p = 0.827). These results indicate that although males were taller and heavier, body composition characteristics were comparable between sexes. Such anthropometric distinctions are consistent with physiological differences typically observed between men and women, particularly regarding muscle mass and force-production potential [9].

Isometric strength data (Table 2) showed that males demonstrated significantly higher back strength (145.40±27.72 kg) compared with females (101.50±18.42 kg, p =0.001). A similar pattern was observed for leg strength, with males reaching 138.50±27.45 kg versus 103.50 ±40.48 kg in females (p=0.028*). These results reflect the well-documented physiological advantage of males in muscle cross-sectional area and neuromuscular activation, which together enhance force production. The higher body height and mass of male participants were also mirrored in their superior strength measurements. This difference can be attributed to greater skeletal-muscle mass and hormonal factors that promote hypertrophy and power output [9]. Previous research has also shown that structured strength and balance programs contribute to improved performance outcomes in athletes [13], and the strength values obtained in this study are comparable to those reported in earlier studies on alpine skiers [3,14].

One of the notable findings, as presented in Table 4, was the moderate negative correlation between leg strength and both descent-related (r=–0.40, p=0.034) and total falls (r = –0.42, p = 0.031), suggesting that greater lower-limb strength helps reduce fall frequency. Back strength, although negatively correlated with all types of falls (r = –0.27 to –0.37), did not reach statistical significance (p >0.05). These results indicate that trunk and lower-limb strength contribute to postural control and stability during skiing. Previous studies have also reported that higher muscular strength supports postural balance and reduces fall risk [3,4].

The Flamingo Balance Test results showed moderate positive correlations between balance score and the number of falls (r = 0.518–0.556, p<0.05), indicating that participants with poorer balance tended to fall more frequently. Individuals who lost their balance repeatedly during the test also showed greater instability in skiing tasks. This finding reinforces that balance ability plays a key role not only in static posture but also in dynamic movements. Previous research similarly emphasized that balance is essential for both safety and performance in skiing [2].

According to Table 3, the highest number of falls occurred during downhill training (3.43±0.77), followed by other skiing activities (2.13 ±0.94), with a mean total of 5.57±1.62 falls per participant. These results indicate that descent techniques place the greatest demands on motor coordination, speed

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control, and postural balance [6,15]. In this context, agility, defined as the ability to change direction rapidly, prevent falls, and execute reactive movements, should be considered a fundamental performance component in dynamic sports [16]. Numerous studies have also confirmed that balance-oriented exercises can significantly reduce fall risk and enhance physical performance [17,18,19].

Taken together, these findings highlight the need to structure ski-training programs not only around technical skill acquisition but also around systematic development of strength and balance capacities. Simple and practical screening tools, such as the Flamingo Balance Test, may help identify individuals with poor balance at early stages of training. Moreover, personalized programs that account for strength asymmetries, limb dominance, and individual balance differences could further improve performance while reducing the likelihood of injury [20]. In line with this, Deva and Turjaka (2023) emphasized that optimizing ground reaction forces, particularly during the steering phase, plays a crucial role in enhancing balance control and overall ski-turn performance [21].

CONCLUSION

The present study demonstrates that fall tendencies among novice skiers are closely related to both muscular strength and balance proficiency. Enhancing these parameters can effectively decrease the frequency of falls, thereby improving both safety and performance during ski training.

However, certain limitations should be acknowledged. The relatively small sample size limits the generalizability of the results. In addition, the Flamingo Balance Test assesses only static balance, whereas skiing primarily demands dynamic balance. Therefore, future studies should involve larger samples and employ research designs incorporating dynamic balance assessments to validate and expand upon these findings.

CONFLICT OF INTERESTS

No potential conflict of interest was reported by the authors.

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