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EVALUATION OF DYNAMIC BALANCE, FUNCTIONALITY AND ANTHROPOMETRIC CHARACTERISTICS IN ALPINE AND NORDIC SKIERS

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ABSTRACT

Purpose: The dynamic balance ability, functionality level, and anthropometric structure of elite athletes are closely related to their performance during sports activities. Therefore, this study was designed to evaluate the dynamic balance, functional performance, and anthropometric characteristics of Alpine and Nordic skiers, which are different ski disciplines, and to investigate the relationships between these parameters.

Methods: The study was carried out on licensed Nordic skiers (n=29) and Alpine skiers (n=33). Dynamic balance was evaluated with the Y Balance Test, and functionality was evaluated with the Single Leg Hop for Distance Test. Sitting height and anthropometric measurements of the lower extremities were taken and recorded.

Results: The Y Balance Test result for Nordic skiers were higher (p=0.007). The results of the Single Leg Hop for Distance Test were similar in both groups (p=0.534). Lower limb length (p=0.044), thigh length (p=0.005), and leg length (p=0.005) were longer in Nordic skiers. A positive moderate correlation was found between the Y Balance Test and Single Leg Hop for Distance Test in both groups (Alpine skiing r=0.583; p <0.001; Nordic skiing r=0.457; p=0.013). A positive moderate correlation was found between sitting height and dynamic balance (r=0.432; p=0.012) and between leg length and the Single Leg Hop for Distance Test (r=0.442; p=0.010) only in Alpine skiers.

Conclusion: In conclusion, this study revealed certain differences regarding the dynamic balance, functional performance, and anthropometric characteristics of Alpine and Nordic skiers and presented guiding results in organizing of training programs for ski disciplines and in the prevention of injuries in ski athletes.

Keywords: Anthropometric Measurements, Balance, Functionality, Skiing

ALP VE KUZEY DİSİPLİNİ KAYAK SPORCULARINDA DİNAMİK DENGE, FONKSİYONELLİK VE ANTROPOMETRİK ÖZELLİKLERİN DEĞERLENDİRİLMESİ

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Elit sporcuların dinamik denge yeteneği, işlevsellik düzeyi ve antropometrik yapısı, spor aktiviteleri sırasındaki performanslarıyla yakından ilişkilidir. Bu sebeple, bu çalışma, farklı kayak disiplinleri olan Alp ve Kuzey disiplini kayak sporcularının dinamik denge, fonksiyonel performans ve antropometrik özelliklerini değerlendirmek ve bu parametreler arasındaki ilişkileri araştırmak üzere tasarlanmıştır.

Yöntem: Çalışma lisanslı Kuzey disiplini kayak sporcuları (n=29) ve Alp disiplini kayak sporcuları (n=33) üzerinde gerçekleştirildi. Dinamik denge Y Denge Testi ile, fonksiyonellik ise Tek Bacak Sıçrama Testi ile değerlendirildi. Oturma yüksekliği ve alt ekstremiteye ilişkin antropometrik ölçümler alınarak kaydedildi.

Sonuçlar: Kuzey disiplini kayak sporcularında Y Denge Testi sonucu daha yüksek bulundu (p=0,007). Tek Bacak Sıçrama Testi sonuçları her iki kayak disiplini grubunda benzerdi (p=0,534). Kuzey disiplini kayak sporcularının alt ekstremite uzunluğu (p=0,044), uyluk uzunluğu (p=0,005) ve bacak uzunluğu (p=0,005) Alp disiplini kayak sporcularına göre daha uzundu. Her iki grupta da Y Denge Testi ile Tek Bacak Sıçrama Testi arasında pozitif, orta düzeyde korelasyon bulundu (Alp disiplini r=0,583; p<0,001; Kuzey disiplini r=0,457; p=0,013). Sadece Alp disiplini kayak sporcularında oturma yüksekliği ile dinamik denge arasında (r=0,432; p=0,012) ve bacak uzunluğu ile Tek Bacak Sıçrama Testi arasında (r=0,442; p=0,010) pozitif orta düzeyde korelasyon bulundu.

Tartışma: Sonuç olarak, bu çalışma Alp disiplini ve Kuzey disiplini kayak sporcularının dinamik denge, fonksiyonel performans ve antropometrik özelliklerine ilişkin belirli farklılıkları ortaya koymuş, kayak disiplinlerine yönelik antrenman programlarının düzenlenmesinde ve kayak sporcularında yaralanmaların önlenmesinde yol gösterici sonuçlar sunmuştur.

Anahtar Kelimeler: Antropometrik Ölçümler, Denge, Fonksiyonellik, Kayak

INTRODUCTION

Skiing, which is performed on a narrow support surface and is very dynamic in nature, is a sport that is mainly divided into Alpine and Nordic disciplines, where balance, flexibility, strength, and anaerobic-aerobic capacity are at the forefront (1,2). Alpine discipline is a high-intensity exercise involving repetitive eccentric and isometric contractions in which the heel and toe are fixed to the ski with a piece called a binding, where gravity acts as a driving force. Nordic discipline, on the other hand, is an aerobic exercise in which only the toe of the foot is fixed to the ski, foot stabilization is less, there is high-intensity muscle activation in the body, and endurance and technical skills are at the forefront (3,4).

Optimal performance during sports activities is closely related to technical and tactical conditions as well as physical and mental sufficiency of the athletes. Considering that most of the sports activities are dynamic and functional, the best performance of an athlete requires several branch-specific parameters (5,6).

Balance, one of these parameters, is an important component for athletes to control their motor activities in many sports branches (7). Therefore, ski athletes should maintain their static body posture during skiing. This results in increased vestibular, visual and somatic inputs during skiing where both environment and ground changes rapidly. During skiing, angular and linear velocity changes increase the role of the vestibular system in the control of body posture, and the visual system provides information about the speed, location and direction changes of the body due to the continuous changes in the recorded image. At the same time, rough terrain, ground characteristics and changes in the body position cause permanent displacement in the athlete's center of gravity. This increases the role of the muscle, joint and skin receptors for maintaining dynamic balance (8).

The safe performance of skiing, which is technically, tactically and physically challenging and complex, requires various components of physical performance (9,10). Strength, range of motion and neuromuscular status of the lower extremities are very important for an individual to fulfill sports-related functional tasks (6). In addition to balance and functional fitness, it is stated that the morphological characteristics and body structure of the athlete are determining factors for performance in many sports branches. For this reason, anthropometric characteristics are very important in terms of predicting the physiological and physical performance of an athlete in the relevant sport branch (11,12).

Therefore, in this study, we aimed to determine the differences between Alpine and Nordic skiers in terms of dynamic balance, functional performance, and anthropometric characteristics. In addition, since we think that the sports performance integrity of the individual in skiing may be related to the ability to provide neuromuscular control and physical structure, investigating the relationships between these parameters constitutes another aim of the study. In this direction, the primary hypothesis of the study was that there was a difference between Alpine and Nordic ski athletes in terms of dynamic balance, functionality, and anthropometric characteristics, and the secondary hypothesis was that there was a relationship between intragroup dynamic balance, functionality, and anthropometric characteristics of Alpine and Nordic ski athletes.

METHODS

This cross-sectional study was conducted between August 2020 and February 2021 in the cities determined by the Turkish Ski Federation. Licensed ski athletes (n=62) between the ages of 16-29 years, registered to the Turkish Ski Federation and participated in the training and preparation camps in the 2020-2021 season activity program in the Alpine Skiing and Nordic Skiing (Ski Running) branches, were included in the study. The preliminary report which clearly stated the aims and methods of our study was submitted to the Turkish Ski Federation and the necessary permissions were obtained. The athletes included in the study were divided into two groups as Nordic ski athletes (n=29; 4 women, 25 men) and Alpine ski athletes (n=33; 7 women, 26 men) in order to evaluate and compare balance, functionality and certain anthropometric characteristics. The athletes with congenital anomalies,rheumatic diseases, history of musculoskeletal

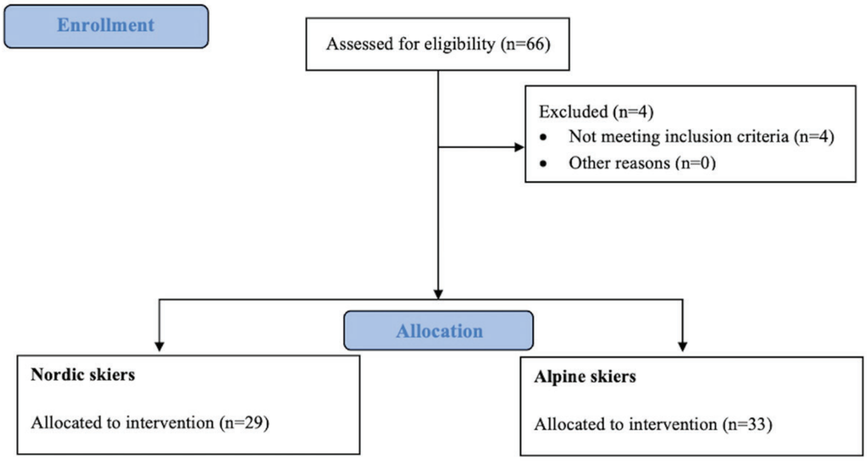

Figure 1. Flow Diagram for Participant Selection

system surgery, and any trauma (deformity,fracture, sprains, and strains) in the last 6 months were not included in the study. Participation in the research was provided on a voluntary basis and voluntary written consent was obtained from the athletes themselves or their legal guardians (Figure 1).

The measurements were made by the same investigator at the same time of day, using the same measuring instruments and techniques. The ethical approval for the study was obtained from Baskent University Medical and Health Sciences Research and Ethics Committees (Date: May 13, 2020, Project No. KA20/167).

The demographic data including age, gender, body weight, height and body mass index (BMI = body weight (kg) / height (m^2) of the participants were recorded in a form prepared by the researcher and balance and functionality evaluations were made based on the determined measurement principles, and anthropometric measurements were taken.

Assessment of dynamic balance

The dynamic balance of lower extremity was evaluated with the Y Balance Test. The test setup was created by sticking a tape in the anterior, posteromedial and posterolateral directions on a flat surface. The 135-degree angle between the anterior and posteromedial, and anterior and posterolateral directions, and the 90-degree angle between the posteromedial and posterolateral directions were determined by measuring with a goniometer. The test center was marked at the intersection of three directions (Figure 2).

Before starting the test, the participant was informed about the content of the test and watched a video on the application of the test. The participants placed their hands with their thumbs and index fingers on their iliac crests and got the starting position on one foot at the test center point. While maintaining the balance, they were asked to reach the maximum distance in the anterior, posteromedial and posterolateral directions with their other leg. The test was applied at right anterior, left anterior, right posteromedial, left posteromedial, right posterolateral, and left posterolateral directions. In order to minimize the differences in foot length, it was requested that the distal big toe be positioned in the test center in the anterior directions, and the most posterior point of the heel to be positioned in the test center in the posteromedial and posterolateral directions. All measurements were performed with bare feet to ensure standardization (Figure 2). To eliminate the learning effect, the participants were allowed to make four trials in each direction before taking test measurements to take 5-minute break between the trials and actual measurements to rest. Test measurements were taken by repeating three times for each direction. The maximum distance that the individual could reach was marked by the researcher, measured with a non-stretchable tape measure, and recorded in the measurement form in cm. During the test, the test was terminated and repeated in cases where the reaching leg could not be returned to the starting position, the unilateral stance could not be maintained, the stance leg was displaced and the reaching leg contacted the ground. The mean of three measurements was used for each direction while evaluating the Y Balance Test results. The mean scores (cm) were calculated for the anterior, posteromedial and posterolateral directions by making necessary calculations in two ski discipline groups, and the normalized reach distance (%) was obtained by dividing these scores by the mean lower limb length and multiplying by 100. The normalized composite reach distance was also calculated (13,14) .

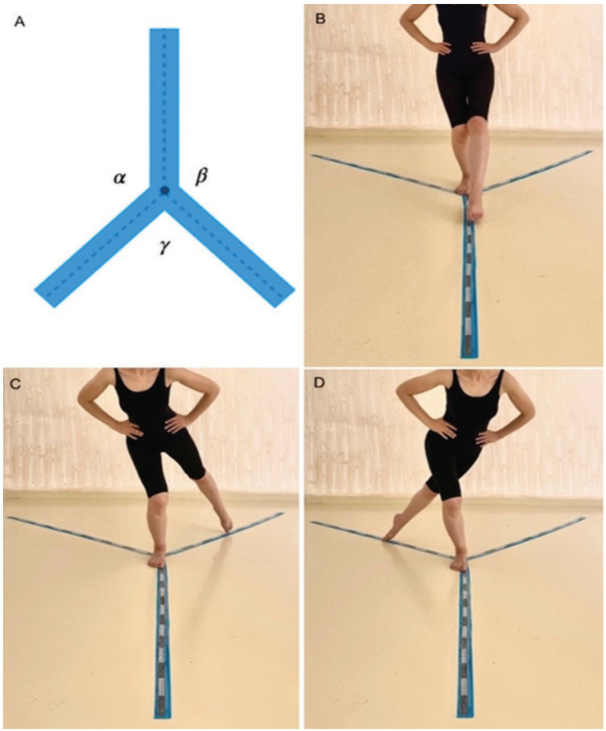

Figure 2. (A) Schematic representation of Y Balance Test (α:135°, β=135°, γ =90°), Application of Y Balance Test (B) right anterior; (C) right posteromedial; (D) right posterolateral.

Normalized reach distance (%):
(Anterior reach distance / Lower limb length) x100
(Posteromedial reach distance / Lower limb length) x100
(Posterolateral reach distance / Lower limb length) x100
Normalized composite reach distance (%):

[(Anterior+ Posteromedial+ Posterolateral) / (Lower limb length x 3)] x100.

Assessment of functionality

The lower extremity functional performances of the participants were evaluated with the Single Leg Hop for Distance Test (15). The test was performed on the participants' dominant extremities. Dominant lower extremities of the participants were determined by the Waterloo Foot Preference Questionnaire- Revised (16). The test setup was prepared by determining the starting line on a flat surface and sticking a tape extending in the horizontal direction perpendicular to this line.

Before starting the test, the content and application of the test were explained to the participant. The participant was asked to take the test with starting position on one foot with the thumbs and index fingers on the iliac crests, the dominant foot on the ground and the distal end of the foot on the starting line. Then, he/she was asked to jump to the maximum distance he/she could jump in the direction of the horizontal line and to maintain this position for a minimum of two seconds after landing. They were allowed to participate in the test with bare feet for standardization of the measurements. The individuals were given the right to try the test once before taking the test measurements. The test was performed by jumping as far as possible on their dominant feet, with three repetitions and a 30-second rest interval between repetitions to avoid fatigue (Figure 3). The heel's back edge's point of contact was marked by the researcher when the participant jumps and lands on the ground, and as a result of the participant's three successful jumps, the distance between the starting line (distal tip of the foot) and the jump point (back edge of the heel) marked during the test was measured with a non-flexible tape measure and recorded in the measurement form in cm. The test was terminated and repeated in case of loss of balance during the test, performing an additional jump during the descent, or contact of the opposite lower extremity or upper extremity with the ground. While evaluating the Single Leg Hop for Distance Test results, the mean of three successful jump scores was used for every participant (17,18).

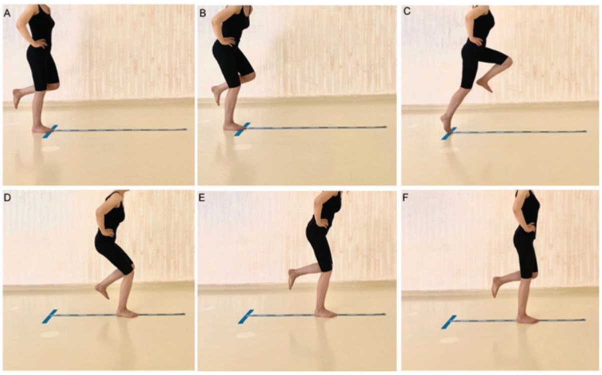

Figure 3. Single Leg Hop for Distance Test

The anthropometric measurements

Sitting height, lower limb length, thigh length, leg length, thigh circumference and leg (calf) circumference were measured as anthropometric measurements in the athletes participating in the study.

Sitting height: the distance between vertex and seating surface (19).

Lower limb length: the distance between the anterior superior iliac spine (ASIS) and the distal point of the medial malleolus.

Thigh length: The distance between the midpoint of the inguinal ligament and the proximal edge of the patella.

Leg length: The distance between the tibial plateau and the medial malleolus.

Thigh circumference: The circumference taken from the midpoint of the distance between the inguinal region and the proximal edge of the patella.

Leg circumference: circumference taken from the most bulging point of the gastrocnemius muscle (20).

Sitting height was measured using a Martin type anthropometer (GPM Model 100, Swiss), and length and circumference measurements were done bilaterally three times by the same researcher using a non-flexible tape measure. In the assessments, the mean measurement values were used without any extremity discrimination.

Sample Size

In this study, the minimum required sample size was calculated based on the primary hypothesis that there are differences between Alpine and Nordic ski athletes in terms of dynamic balance, functionality and anthropometric characteristics. Firstly, for the Two Independent Sample t test (Student's t test), which directly addresses the primary hypothesis, a total of 52 participants, 26 in each group, are required for an effect size (d) of 0.80, 80% test power, and 95% confidence level. The secondary hypothesis, which explores the relationship between dynamic balance, functionality, and anthropometric characteristics within each group of Alpine and Nordic ski athletes, was investigated using Pearson correlation analysis. For this test, a total of 58 participants are required for an effect size (ρ) of 0.50, 80% test power, and 95% confidence level. Therefore, 29 athletes from the Alpine Skiing group and 29 athletes from the Nordic Skiing group, for a total of 58 athletes, were found to be the minimal sample size needed to test all of the study's hypotheses. In the calculation of the sample size, Cohen's large effect size values were employed (21). Sample size calculations were performed using G*Power software (version 3.1, Universität Düsseldorf, 2020).

Statistical analysis

The conformity of the numerical variables to the normal distribution was analyzed with Shapiro-Wilk normality test. For numerical variables conforming to normal distribution, the descriptive statistics were presented as the mean ± standard deviation, and the median (minimum-maximum) values were given for the variables not conforming to the normal distribution. The statistical difference between the groups in terms of the distribution of numerical variables was examined with the Student's t test (Independent Sample t test) when the assumptions of normal distribution were met, and with the Mann-Whitney U test when the assumptions were not met. Correlation analysis was performed to examine the relationships among the measurement variables. Pearson Correlation Coefficient was presented when parametric test assumptions are met, and Spearman Correlation Coefficient was presented when not. When evaluating the correlation results, the absolute value of the correlation coefficient (r) was defined as low correlation or no correlation if $r<0.20$, weak correlation if 0.20-0.39, moderate correlation if 0.40-0.69, high correlation

Table 1. The Demographic Characteristics of Alpine and Nordic Skiers

	Alpine Ski Athletes (n=33)		Nordic Ski Athletes (n=29)		p
	Mean ± SD	Med (min-max)	Mean ± SD	Med (min-max)	
Age (years)	19.18±2.47	19 (16-25)	20.90±3.41	20 (16-29)	0.050[b]
Body Weight (kg)	67.36±11.10	68 (46-84)	68.22±12.03	70 (41-92)	0.771[a]
Height (cm)	172.94±6.58	174 (158-183)	176.28±7.49	178 (155-187)	0.067[a]
BMI (kg/m²)	22.48±3.24	21.98 (15.70-29.36)	21.83±2.87	21.98 (17.07-28.40)	0.412[a]

Data are presented as mean ± SD and median (min-max), * p< 0.05, a: Student t test, b: Mann-Whitney U test, BMI: Body mass index, cm: centimeter, kg: kilogram, m²: meter square, Med: Median, min: minimum, max: maximum, SD: Standard deviation.

Table 2. Comparison of Dynamic Balance and Functionality Measurements Between Groups

	Alpine Ski Athletes Mean ± SD Med (min-max)	Nordic Ski Athletes Mean ± SD Med (min-max)	p
YBT Anterior (%)	84.72 (63.35-136.56)	96.51 (69.75-131.97)	0.072[b]
YBT Posteromedial (%)	93.23±15.14	104.44±14.00	0.004[a*]
YBT Posterolateral (%)	84.52 (55.09-110.93)	93.03 (57.32-128.43)	0.036[b*]
YBT Composite (%)	89.17±14.33	99.03±13.41	0.007[a*]
Single Leg Hop for Distance Test (cm)	110.59±33.98	115.22±23.91	0.534[a]

Data are presented as mean ± SD and median (min-max), * p< 0.05, a: Student t test, b: Mann-Whitney U test, cm: centimeter, Med: Median, min: minimum, max: maximum, SD: Standard deviation, YBT: Y Balance Test.

if 0.70-0.89, and very strong correlation if 0.90-1.00 (22).

Intraclass correlation coefficient (ICC) was calculated to evaluate the measurement reliability of the researcher who made the measurements, and the participant's reliability regarding balance and functionality tests. The ICC model was chosen as the average measures two-way mixed model, and absolute agreement values were obtained. Type 1 error probability was determined as α=0.05 in all hypothesis tests, and SPSS v25.0 package program (Statistical Package for the Social Sciences package program version 25.0, SPSS Inc., Chicago, IL, USA, 2017) was used for the statistical analyses.

RESULTS

Licensed Alpine Skiers (n=33, 7 women, 26 men) and Nordic skiers (n=29; 4 women, 25 men) aged between 16 and 29 years, registered to the Turkish Ski Federation and included in the 2020-2021 season activity program, were included in our study. The demographic characteristics of the partici-

Table 3. Comparison of Anthropometric Measurements Between Groups

Anthropometric measurements (cm)	Alpine Ski Athletes Mean ± SD Med (min-max)	Nordic Ski Athletes Mean ± SD Med (min-max)	p
Sitting height	87.80±3.92	89.68±3.80	0.061[a]
Lower limb length	90.86±3.60	93.33±5.48	0.044[a*]
Thigh length	38.29±1.52	39.72±2.26	0.005[a*]
Leg length	36.92 (32.75-39.53)	38.25 (32.33-41.00)	0.005[b*]
Thigh circumference	49.75±5.61	48.37±4.61	0.298[a]
Leg circumference	34.53 (30.00-42.50)	34.50 (27.50-39.50)	0.494[b]

Data are presented as mean ± SD and median (min-max), * p< 0.05, a: Student t test, b: Mann-Whitney U test, cm: centimeter, Med: Median, min: minimum, max: maximum, SD: Standard deviation.

Table 4. The Relationship of Intragroup Dynamic Balances of Disciplines with Functionality and Anthropometric Measurements

	Y Balance Test Composite (%)			
	Alpine Ski Athletes (n=33)		Nordic Ski Athletes (n=29)	
	Correlation coefficient	p	Correlation coefficient	p
Single leg hop for distance test (cm)	0.583	0.001[a*]	0.457	0.013[a*]
Sitting height (cm)	0.432	0.012[a*]	0.063	0.746[a]
Lower limb length (cm)	0.318	0.072[a]	0.004	0.983[a]
Thigh length (cm)	0.294	0.096[a]	-0.047	0.808[a]
Leg length (cm)	0.286	0.107[a]	-0.021	0.913[b]
Thigh circumference (cm)	-0.233	0.192[a]	0.120	0.535[a]
Leg circumference (cm)	-0.107	0.554[b]	0.120	0.535[a]

Data are presented as correlation coefficient, * p<0.05, a: Pearson correlation coefficient, b: Spearman rho correlation coefficient, cm: centimeter.

pants are presented in Table 1, and there were no statistically significant differences between Alpine and Nordic skiers in terms of the characteristics of the participants (Table 1).

The Intraclass Correlation Coefficient (ICC) values and 95% Confidence levels we obtained as a result of the repeated measurements we performed are as follows: 0.994-1.000 for anthropometric measurements, 0.912-0.967 for Y Balance Test value and 0.953 for Single Leg Hop for Distance Test. These ICC values indicate that our measurements have a high level of repeatability (22).

The dynamic balance values of Alpine and Nordic skiers regarding the three dimensions of the Y Balance Test, the composite balance value and the measurement results of the Single Leg Hop for Distance Test are presented in Table 2. When the dynamic balances of Alpine and Nordic skiers were compared regardless of extremity, there was no significant difference in the anterior direction (p=0.072), however the balance values in the posteromedial (p=0.004) and posterolateral (p=0.036) directions were higher in Nordic skiers. When the dynamic balances of Alpine and Nordic skiers were compared in terms of composite balance value without any extremity and direction discrimination, the composite balance value of Nordic skiers was higher than Alpine skiers (p=0.007) (Table 2).

No statistically significant differences were found between Alpine and Nordic skiers in terms of the functionality measurements evaluated with the Single Leg Hop for Distance Test (p=0.534) (Table 2).

Anthropometric measurements of Alpine and Nordic skiers were similar in terms of sitting height, thigh circumference or leg circumference (p>0.05).

Table 5. The Relationship Between Disciplines' In-Group Anthropometric Measurements and Functionality

	Single Leg Hop for Distance Test (cm)			
	Alpine Ski Athletes (n=33)		Nordic Ski Athletes (n=29)	
Anthropometric measurements (cm)	Correlation coefficient	p	Correlation coefficient	p
Sitting height	-0.030	0.870[a]	0.301	0.112[a]
Lower limb length	0.288	0.105[a]	0.260	0.173[a]
Thigh length	0.262	0.141[a]	0.179	0.354[a]
Leg length	0.442	0.010[a*]	0.211	0.272[b]
Thigh circumference	0.146	0.416[a]	0.250	0.190[a]
Leg circumference	0.206	0.251[b]	0.175	0.365[a]

Data are presented as correlation coefficient, * p<0.05, a: Pearson correlation coefficient, b: Spearman rho correlation coefficient, cm: centimeter.

Lower limb length (p=0.044), thigh length (p=0.005) and leg length (p=0.005) were significantly longer in Nordic skiers compared to Alpine skiers (Table 3).

The relationships of Y Balance Test composite balance values with Single Leg Hop for Distance Test and anthropometric measurements are presented in Table 4 for Alpine and Nordic skiers. A positive moderate relationship was found between Y Balance Test and Single Leg Hop for Distance Test in both ski discipline groups (Alpine skiing r= 0.583; p <0.001; Nordic skiing r= 0.457; p=0.013). When the relationship between Y Balance Test and anthropometric measurements was examined, a positive moderate correlation was found between sitting height and composite balance value only in Alpine skiers (r=0.432; p=0.012) (Table 4).

When the relationship between the anthropometric measurements of Alpine and Nordic skiers and the Single Leg Hop for Distance Test was examined, a moderate positive correlation was found only between the leg length of Alpine skiers and the Single Leg Hop for Distance Test (r=0.442; p=0.010) (Table 5).

DISCUSSION

The main findings of our study, in which we compared Alpine and Nordic ski athletes, were that dynamic balance was better in Nordic ski athletes than Alpine ski athletes and that lower limb, thigh, and leg lengths were longer in Nordic ski athletes.

The success in a high-level competition depends on performance judged in fractions of a second for professional skiers. Therefore, it is very important to know the factors that may affect or limit the ski performances of the athletes (23). In addition to internal factors such as the athlete's anthropometric characteristics, ski racing technique or biological maturity, the ability to provide neuromuscular control and functional fitness are effective on the performance success and injury risk (10).

In this context, the results of our study on Alpine and Nordic skiers were compared with similar studies in the literature, since there are very few studies on the evaluation and comparison of dynamic balance, functionality and anthropometric characteristics in skiers. Noe and Paillard investigated the relationship between postural control and the level of expertise in regional and national Alpine ski athletes, and reported the detrimental effect of the athletes' rigid ski boots the on postural control in the long term due to the mechanical restriction of ankle movements. The authors stated that this affects the postural control of the athletes negatively in cases of static and mediolateral instability, however postural control is not affected in case of anteroposterior instability since the boots allow some ankle movement in the sagittal plane (24).

This result made us think that the dynamic balance is better in Nordic skiers, as the ski boots used in the Nordic discipline allow ankle movement more, unlike the ski boots used in the Alpine discipline. Cote et al. studied on healthy volunteers and investigated the effects of pronated and supinated foot postures, as determined by navicular-drop measures, on static and dynamic postural stability. The authors stated that the individuals with the supinated foot posture had a greater limit of stability in the lateral direction due to the pressure they applied to the lateral edge of the foot, while the individuals with the pronated foot posture had a decreased ability to provide a stable support due to the tendency to collapse towards the medial edge of the foot, and their foot mobility increased (6). Considering that the weight-bearing foot takes a sustained pronation position during the turns in Alpine skiing races held at high speed, we think that the pronator foot muscles of Alpine ski athletes may be stronger than the supinator foot muscles, and this may straighten the medial longitudinal arch. For this reason, as Cote et al. stated in their study, we think that the increased foot mobility with the flattening of the medial longitudinal arch affects the dynamic balance negatively in Alpine ski athletes. In their study on individuals with chronic ankle instability, Hubbard et al. found a positive correlation between the posteromedial and posterolateral reach of the Star Excursion Balance Test and the abduction and extension strength of the hip (25). Differently, in our study, in which we included healthy ski athletes, when Nordic ski running races are examined in terms of movement patterns, the athlete's successive hip extension and abduction movements during running and repetitive contractions will increase extensor and abductor muscle strength. This explains our finding concerning longer posteromedial and posterolateral reach distance in the Nordic skiers when compared to the Alpine skiers.

In our study, we compared the functional performance of the lower extremity with the Single Leg Hop for Distance Test in Alpine and Nordic skiers and did not find any significant difference between the groups in terms of functional performance parameter. We think that the fact that both groups of athletes use their lower extremities very actively and functionally during both races and training supports this situation.

Alpine and Nordic ski athletes, whom we compared in terms of anthropometric characteristics, were compared similarly by Alaeddinoğlu on 13 Alpine and 15 Nordic skiers. Our study is parallel to Alaeddinoğlu's study in terms of measurement groups and parameters, and our results are similar to Alaeddinoğlu's results: the sitting height was higher in Nordic skiers compared to Alpine skiers, and thigh and leg circumferences were greater in Alpine skiers compared to Nordic skiers, however, the differences were not statistically significant. Contrary to Alaeddinoğlu's results, we found significantly longer thigh length and leg length in Nordic skiers compared to Alpine skiers (26).

Haksever et al., on the other hand, investigated the effect of standard balance training on balance and functionality in healthy individuals, and reported a significant positive improvement in dynamic balance and functionality at the end of the training (15). This situation made us think that the dynamic balance that develops with balance training also affects the functionality of the individuals positively, and concerning our study, it supports the significant correlation between dynamic balance and functionality in both ski discipline groups.

Lesnik et al. tested national Alpine skiers over two competitive seasons, U14 (12-13 years) and subsequently U16 (14-15 years), concluded that the balances of participants were maintained regardless of the significant changes in their anthropometric statuses including body mass and body length and stated this finding supported the studies that found skiing as an effective balance exercise (27). In our study, there was no significant correlation between the anthropometric measurement values of the lower extremities of Alpine and Nordic skiers and their dynamic balance, and as Lesnik et al. stated in their study, we think that this is due to continuous protection and improvement of the balance of the athletes in skiing, independent of their anthropometric characteristics.

Yıldırım and Özdemir investigated the relationship between the anthropometric characteristics of 56 male handball players and their jump distances, and reported that the horizontal jump distance increased as the leg length increased. This was explained by the contribution of leg length to anaerobic power as well as its effect on explosive strength. When the relationship between leg length and Single Leg Hop for Distance Test was examined in our study, a significant correlation was found in the Alpine skiing group, similar to the study of Yıldırım and Özdemir (28). On the other hand, Temur reported that the thigh and leg circumferences did not have a significant relationship with the vertical and horizontal jump distance in 54 university students actively doing sports in different branches. In our study, the absence of a significant correlation between the circumference measurements of Alpine and Nordic skiers and the Single Leg Hop for Distance Test was similar to Temur's results (29).

In conclusion, this study revealed certain differences regarding the dynamic balance, functional performance and anthropometric characteristics in Alpine and Nordic skiers, and presented guiding results in order to observe the relationships among these values. The findings of our study show that dynamic balance is better in Nordic ski athletes than in Alpine ski athletes. Length measurements of the lower extremities were also found to be longer in Nordic ski athletes. Additionally, our study revealed a positive relationship between balance and functionality in ski athletes. We think that our results constitute a reference for the selection of athletes' exercises suitable for their skiing discipline, and in this context, the training programs planned to improve balance and functional performance will contribute positively to the performance success of the athletes and will be effective in preventing activity-related injuries. However, we believe that the anthropometric measurement results obtained from Alpine and Nordic ski athletes are instructive in directing individuals to sports branches suitable for their physical structures at an early age.

This study has a number of limitations. Conducting the study during the pandemic condition made it difficult to reach the desired number of athletes in the research population. For this reason, the limitations of the study are that the age distribution could not be performed in a certain group (31 adults or 31 adolescents) and the measurements of a small percentage (12.9%) of the population participating in the study were taken during the camp. Moreover, although the distribution of men and women in the participant groups is not homogeneous, the same applies to both groups. Another limitation of this study is that the distribution of men and women is not homogeneous due to the low number of female athletes in this sport.

At the same time, we think that the data obtained from our study will be useful for physiotherapy and rehabilitation, medicine, and sports sciences, and we suggest that the anthropometric differences of the athletes related to heredity and the training age of the athletes should be taken into consideration in future similar studies.

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