The Effect of 9 Weeks of Various Balance Training Methods on Ski Instructors

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Abstract

In alpine skiing, balance is widely regarded as one of the most important motor skills. However, there are not enough studies in the alpine skiing literature on balance training, balance outcomes, intensity, duration, and frequency of balance training protocols. Although balance ability is a performance factor, there have been few studies on the effect of balance on alpine skiing, and the results have varied. **Objectives**. Given the inconsistency of results reported in studies, this study aims to develop a static and dynamic balance protocol to improve balance values and optimize sports performance in alpine skiing. **Design.** Bifactorial mixed, an intervention study, which comprises nine weeks of five training methods that have been shown to be effective in previous studies. Each method, depending on its specificity, develops different aspects of balance: neuromuscular training, plyometric training, core stability training, proprioceptive training, and balance training with equipment. **Participants.** Twenty-four authorized ski instructors were recruited and divided into an experimental group and a control group. **Measures.** On snow test with CARV device that measures 4 variables: SKI IQ, balance, edging, and pressure and tests on dry-land with ISO FREE, a stabilometric platform with a stable surface measuring seven variables. All variables were retested after the balance training protocol. **Results**. The results show significant improvements in the experimental group in the skier technique represented by the SKI IQ variable ($F_{(1,18)}$=34.45; p=0.000; ηp2=0.65). In addition to this, the results show statistically significant improvements in two-legged balance with eyes closed represented by lower values of standard deviation from COP in the anteroposterior (F=24.952;p=0.000) and mediolateral plane (F=4.891;p=0.038), as

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well as in right-legged balance in the mediolateral plane(F=7.307;p=0.13). **Conclusion**. Balance training for 9 weeks has a positive effect on balance performance and this complex balance development method can improve certain parameters of the static and dynamic balance of alpine skiers.

Keywords: *balance training, dry-land training, alpine ski training.*

1. Introduction

Alpine skiing is one of the most popular winter sports (Steidl-Müller et al.,2019), with millions of people participating at various levels. It is extremely complex and physically, technically, and tactically demanding (Gilgien et al., 2018; Hydren et al., 2013).

While technical ability appears to have the greatest influence on performance in skiing, the ability to consistently display technical ability within a race and over a long competitive season requires a high physiological capacity (Turnbull et al., 2009; Ferland & Comtois, 2018).

Moreover, alpine skiing is extremely complex because performance requires a combination of multidisciplinary parameters such as strength, coordination, technique, mental preparation, and season planning (Hébert-Losier et al., 2014).

Nevertheless, physical abilities are essential in alpine ski performance and should be trained and tested, as events range from 50 seconds to 2.5 minutes. Several studies have investigated the relationship between performance factors, and it emerges that the skier must be highly trained in the following physical abilities: aerobic and anaerobic capacities, muscular strength, and complex motor skills such as balance, agility, and coordination (Maffiuletti et al., 2006; Patterson et al., 2009; Platzer et al., 2009; Raschner et al., 2013).

Furthermore, alpine skiing necessitates developed motor skills in addition to aerobic and anaerobic capacity and strength. According to some researchers, incorporating specific balance training may be a factor in improving performance (Lesnik et al., 2017.; Slomka et al., 2018; Zech et al., 2010). Thus, the neuromuscular system must be properly trained in order to effectively engage the balance on the downhill slope and prevent falls (Morrissey et al.,1987).

Balance is widely recognized as one of the most important motor skills in alpine skiing (Hydren et al., 2013, Malliou et al., 2004). Alpine skiing is a high-intensity sport that causes lactate buildup, muscular hypoxia, and peripheral neuromotor fatigue, all of which contribute to and affect pro-perceptual depreciation and injury risks (alterate balance ability) (Raschner et al., 2012).

Additionally, Hydren et al. (2013) assert that alpine skiing is characterized by instability with ski-snow interaction, particularly on soft snow and rutty course conditions, and that balance workouts may enhance physical patterning for uncertain conditions by utilizing neurologic adjustments. Therefore, the quality of descent is primarily reflected by a high level of specific motor skills that have a dominant and complex effect on situational efficiency (Male et al., 2013). DeCouto et al. (2020) report that the specific practice of sport can simultaneously develop physiological capacities and necessary technical skills.

According to Nashner (1997), balance is defined as the process of keeping the body's center of gravity vertically over the base of support by relying on rapid and continuous feedback from visual, vestibular, and somatosensory structures and then performing smooth and coordinated neuromuscular actions. This ability is influenced by a variety of factors, including sensory information (from the somatosensory, visual, and vestibular systems), joint range of motion, and force (Palmieri et al., 2002), and is in place to assure the proper execution of multiple sports movements as well as injury prevention (Ricotti, 2011). In addition to this, adequate balance control in the performance of motor skills relies primarily on muscle synergies that minimize center of gravity shifts (Ricotti, 2011). This serves as the foundation for the correct execution of complex technical gestures while also reducing the risk of injury (Ricotti, 2011). Balance capacity is categorized in sports performance as static and dynamic (Ricotti, 2011).

Although balance ability is a performance factor there are few studies investigating the effect of balance on alpine skiing and results vary. Some studies on the effect of interventions on balance ability in alpine skiing show a positive effect after an intervention on the dry land of eight, respectively nine weeks (Cillik & Razusova, 2014; Vitale et al., 2018), while others report no differences between experimental and control groups (Mahieu et al., 2004; Malliou et al., 2006).

Our hypothesis assumes that through a balance development training protocol included in a general plan for the development of the skier's physical abilities as well as through exercises from different methods for the development of balance ability, we will be able to improve sports performance by developing balance performance.

Given the inconsistency of previous research findings and the debate over the effect of balance training on improving and optimizing sports performance in alpine skiing, the research aims to use a balance development protocol to improve balance values and sports performance in alpine skiing.

2. Material & methods

2.1. Experimental approach and participants

The study included 24 subjects randomly divided into a control group (CG) (n=12) and an experimental (EG) (n=12) group. Twenty subjects were tested in the initial and final on-snow tests, and 24 subjects were tested in the dry-land tests. The research subjects are included according to the following characteristics: ski instructors accredited by AMPSR (Association of Professional Ski Instructors in Romania), aged between 25-35 at the time of initial testing, and clinically healthy. Subjects were informed of the purpose of the study and gave written consent to participate in the study. The tests were performed in the same time interval and the manner of testing was similar so that there were no errors in the experiment. In the snow tests, the same route was set for all subjects for the initial and final test, and subjects were tested on the same ski - Atomic Doubledeck GS with the following characteristics: length - 178; average width - 71 mm; weight 2.68 kg. The difference between the experimental and the control group is the application of the independent variable, i.e. the application of training to develop balance. Balance training took place twice a week for nine weeks in September, October, and November as individual training on nonconsecutive days. Each session lasted 45 to 60 minutes and each session started with a standard warm-up. The skiers in both groups were assessed with a CARV device which generates SKI IQ, BALANCE, EDGING, and PRESSURE values, and an ISO FREE (Tecnobody, ITALY) force plate which generates center of pressure (COP) standard deviations in F-B (anterior-posterior) [mm] and M-L (medial-lateral) [mm] direction.

2.2. Procedures

On snow test with CARV device

Following a descent on a giant slalom course set up with 20 gates, with a distance between gates of 20 meters, and an identical level difference, CARV assessed several parameters including balance, edging, pressure, and SKI IQ, which is the weighted average of the other parameters. The best descent out of two was taken into account. The CARV (Motion Metrics Ltd, London, UK) device is an inertial motion unit with 72 pressure sensors, motion sensors, accelerometer, gyroscope, and magnetometer and is composed of an insole and a transmitter which sends data to the app (app version 5.5.1-1676).

Balance assessing with an ISO FREE force platform

The support base of the force plate is a sensing platform with four load cells capable of detecting the subject's ground force distribution in real-time (Iso-Free | TecnoBody, 2018). The ISO FREE force platform is a highly sensitive stabilometric plate certified with MEDICAL APPARATUS (class I) with a ground resolution of 1 mm and an acquisition frequency of 20 Hz (Iso-Free | TecnoBody, 2018).

Balance assessment protocol from standing on two legs with eyes closed (DSEC) in antero-posterior (F-B) [mm], medial-lateral (M-L) [mm]: to begin the assessment, the researcher positioned the athlete's feet on the stability platform using the appropriate alignments for the medial malleolus and the outside border of the heel. The subject position was with hands on hips, feet slightly apart on force plate indicators. The subject was told to stand as still as possible for 30 seconds. The average of the best effort in two 30-second attempts was used for evaluation. The apparatus measures the

COP standard deviation from the ideal upright position in F-B (antero-posterior) and M-L (mediolateral) directions

Balance assessment protocol on the left and right leg respectively with standard deviations of the COP in the F-B [mm] and M-L [mm] direction with eyes open: subject's position was standing on one leg, hands on hips; the other leg slightly flexed resting on the outer malleolus of the supporting leg for 30 seconds. The subject was told to stand as still as possible for 30 seconds The average of the best effort in two 30-second attempts was used for evaluation.

Protocol for the limit of stability (LOS) with COP displacements: As in the study of Juras et al. (2008) subjects were instructed to stand on the force platform barefoot, with their legs in a comfortable position and their arms across their thighs, palms facing their thighs. They kept their heads horizontal and looked ahead. The fixation point was placed on the screen in front of the subjects, 2 meters away from them. Subjects completed 2 consecutive maximal voluntary leaning trials (limits of stability test - LOS test) in the 8 directions (suggested by the platform software), with about 2 minutes of rest in between the trials. For all force plate test indices, a greater inclination from the ideal vertical position over the support base generates a higher numerical value, indicating greater instability. In other words, lower values of the center of pressure path (COP) and body sway indicate a better degree of balance (Staniszewski et al., 2016).

2.3. Balance training protocol

Alpine skiing being a complex sport, we have chosen to use 5 types of training that are effective in other studies as a method of balanced development. Each method has its own specificity and develops certain sides of the balance. The balance training protocol for EG was developed from findings from other research. We chose neuromuscular training as a method of balance development because it has been shown in other studies (Hewett et al., 1999; Mandelbaum et al., 2005; Zazulak et al., 2007) to improve postural stability. Also, we chose to include core stability training as a method of balance development because previous research has shown that performance of core stability exercises improves balance ability and postural control in athletes (McLeod et al., 2009) and healthy adults (Shah & Varghese, 2014). The other areas are plyometric training (Alikhani et al., 2019.; Hewett et al., 1999; McLeod et al., 2009; Myer et al., 2006.; Słomka et al., 2018; Steffen et al., 2008), proprioceptive training as described in Table 1 (McLeod et al., 2009) and balance development training with apparatus, all of which have positive values in balance development. Training took place twice a week for 9 weeks (17 sessions), with a session duration of 45 to 60 minutes. Each session started with a standard warm-up. The sessions were led by a certified fitness trainer who provided verbal and visual feedback on exercise techniques. Furthermore, the fitness trainer stimulated the athletes to focus on movement efficiency. The proportion of sessions attended during the experimental protocol for EG was used to fully comply with the balance program. Participants had to complete 90% of the balance intervention program to be considered compliant.

Table 1. Proprioceptive training adapted from McLeod et al. (2009) (sample)

Exercise	Series and repeats	Time (sec)	Rest (sec)
Balance on two legs on half a foam roll	3	30	A 30
Two-legged balance on half a foam roll by rolling a ball along the torso	3	30	A 30
Maintaining balance on 1 foot on half foam roll inclination A/P	3L – 3R	30	P 30
Maintaining balance on 1 foot on half of foam roll inclination M/L	2L – 2R	30	P 30
Sidestep on the half foam roll, inclination M/L	15L- 15R		P 30
Forward step on half foam roll inclination A/P	15L – 15R	5	P 30
Squat on the half foam roll	2x10		A 30

Notes: P=passive rest; A=active rest; L=left limb; R=right limb

2.4. Statistical Analysis

Statistical processing was performed with Statistical Package for the Social Sciences (SPSS) (version 1.0.0.1275; SPSS Inc, Chicago, IL). Basic descriptive statistics were calculated (mean, standard deviation). To test the assumption of normality of the distribution, we used the Skewness and Kurtosis indicators. We also used multivariate analysis (MANOVA) for the presence of multiple dependent variables. In addition to this, we used partial eta squared (η2) which shows how much of the variance is explained by the independent variable. This is used as the effect size for the MANOVA model to report the magnitude of the effect with the following interpretation: .001-.05 = small effect, .06-.13 = medium effect, ≥.14 = large effect. The significance threshold for the tests used was $\alpha = 0.05$. We used a MANOVA to see if the experimental group differed from the control group before the intervention because we randomized subjects into two groups (experimental vs. control). Furthermore, we conducted a MANOVA because we had several variables as dependent variables at snow test, including Ski IQ, balance, edging, and pressure, also at balance assessing with ISO FREE force platform the following variables: DSEC (double leg stance eyes closed) both direction FB/ML, LOS (limit of stability), OLSL (one leg stance left limb) both direction FB/ML, OLSR (one leg stange right limb) both direction FB/ML, as well as membership in the control or experimental group as an independent variable.

To compare the experimental group with the control group after the intervention, we decided to create 4 new dependent variables for the snow test, as well as 7 new variables on balance assessment with the ISO FREE, which are equal to the difference between post-intervention (post-test) and pre-intervention (pretest). We did this because, in addition to the difference observed in the experimental group, we observed an increase from the pretest to the posttest in the control group.

3. Results

3.1. On snow testing

Skewness and Kurtosis values range from -1 and 1, which means that there are no significant deviations from the normality of the dependent variables. The differences between the 2 groups in the 4 dependent variables before the intervention are not statistically significant. For example, the difference in Ski IQ between control and experimental is statistically insignificant (F=0.613; p=0.444). The other differences are also not statistically significant, balance (F=0.065; p=0.801), edging (F=1.047; p=0.320), pressure

(F=0.002; p=0.962). Thus, we can conclude that the 2 groups are equivalent before the intervention, and thus, that randomization worked. In order to compare the experimental group with the control group after the intervention, we decided to create 4 new dependent variables, which are equal to the difference between post-intervention (posttest) and pre-intervention (pretest). As a result, by calculating pretest-posttest differences as shown in Figure 1, for both the experimental and the control groups, we can test the extent to which our intervention was effective beyond the "natural" increase observed in the control group. We report a significant difference in Ski IQ ($F_{(1,18)}$=34.45; p=0.000; ηp2=0.65) and can state with a 95% probability that the results obtained are not random and are the effect of the intervention protocol. As for the other dependent variables, the differences are not statistically significant: balance difference ($F_{(1,18)}$=1.96; p=0.178; ηp2=0.98), edging difference ($F_{(1,18)}$=2.99; p=0.101; ηp2=0.143), pressure difference ($F_{(1,18)}$=1.32; p=0.265; ηp2=0.69). Even though these differences are not statistically significant, in terms of effect size they are large and medium.

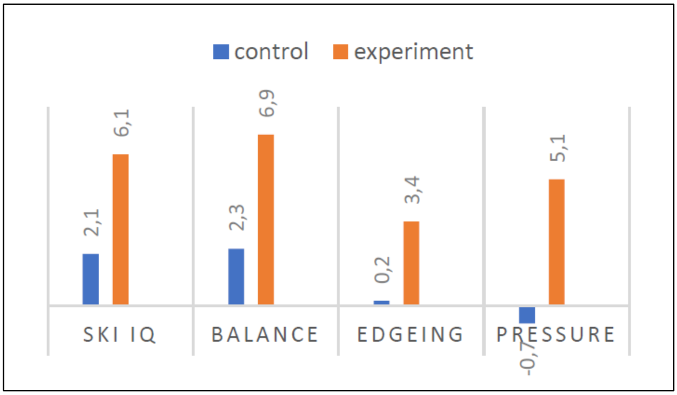

Figure 1. Mean pretest-posttest difference Carv variables

3.2. Balance assessing with ISO FREE force platform

The differences between the 2 groups in the 7 dependent variables are not statistically significant. The difference between DSEC FB between control and experimental is not statistically significant (F=0.778; p=0.387). The other differences are also not statistically significant, DSEC ML(F=2.078; p=0.164), LOS (F=0.065; p=0.801), OLSL FB (F=0.003; p=0.957). Thus, we can conclude that the 2 groups are equivalent before the intervention, and thus, that randomization worked. In the next step, we created 7 new dependent variables (making the difference between the post-test and pretest scores for each participant). Following the MANOVA analysis, we report statistical significance at the $p < 0.05$ threshold for the variable Difference DSEC FB (F=24.952;p=0.000). Also, the balance training induced significant changes after the intervention on the variable difference DSEC ML which shows statistical significance (F=4.891; p=0.038) as described in Table 2. The data indicate an increase in the variable balance on the right leg in the mediolateral (Difference OLSR) following the intervention which shows statistical significance (F=7.307;p=0.13). And in terms of effect size, the values are large and medium in 5 of the calculated variables, except with a small effect size of the variable LOS (ηp2=0.14) and OLSL FB with a medium effect size (ηp2=0.069).

Table 2. Differences between the control group and experiment inferential analysis

Variable	*Sum of squares*	*Degrees of freedom*	*Mean squares*	*F*	*P*	*η2*
Difference DSEC FB	18,096	1	18,096	24,952	0,000*	0,531
Difference DSEC ML	1,955	1	1.955	4,891	0,038*	0,182
Difference LOS	1,021	1	1,021	0,307	0,585	0,14
Difference OLSL FB	2,394	1	2,394	1,624	0,216	0,069
Difference OLSL ML	3,197	1	3,197	3,874	0,062	0,150
Difference OLSR FB	2,660	1	2,660	2,568	0,123	0,105
Difference OLSR ML	3,161	1	3,161	7,307	0,13*	0,249

Notes* sign indicates statistical significance; η2= partial eta squared; p=probability value;

4. Discussion

The study aimed to verify the effect of training for balance development in alpine skiing in ski instructors, in order to develop dynamic and static balance, aiming at increasing sports performance, as well as to verify different training methods for balance development (plyometric, neuromuscular, proprioceptive, balance training with apparatus and core stability training).

We started from the hypothesis that balance development training using various methods would result in significant changes in balance performance in alpine skiing. . Our study finds significant improvements in skier technique, as measured by the SKI IQ variable, which is a weighted average of the other values (balance, edging and pressure) knowing that alpine skiing is a technical sport with significant implications for the athlete's physical and motor abilities (Raschner et al., 2017). Pérez-Chirinos Buxadé et al. (2022) report that the ski turn is an essential technical aspect of speed regulation and the goal is to make turns while losing as little speed as possible. According to Komissarov (2020), the main advantage of the carv turns technique in terms of performance is the significant reduction in energy dissipation, which results in increased speed (Komissarov, 2020). The most important aspect of alpine ski racing, according to Hydren et al. (2013), is to maintain a carv turn while resisting the forces generated while maintaining the edge and balance control.

Hébert-Losier et al. (2014) report that balance ability is important but there are very few publications on balance development in alpine skiing. Furthermore, alpine skiing, according to Noe and Paillard (2005), is a sport that requires great postural stability to achieve balance in difficult conditions. Exercises for balance development were chosen and adapted from other studies that documented positive effects after balance intervention by the following five methods: neuromuscular training (Vitale et al., 2018), core stability training (Myer et al., 2006.; Słomka et al., 2018; Steffen et al., 2008), balance development training with apparatus (Engebretsen et al., 2008; Kovacs et al., 2004; Panics et al., 2008; Słomka et al., 2018; Verhagen et al., 2004), plyometric training (Alikhani et al., 2019.;

Hewett et al., 1999; McLeod et al., 2009; Myer et al., 2006.; Słomka et al., 2018; Steffen et al., 2008) and proprioceptive training.

Several other studies share positive results on balance performance and are similar to our study. There are studies reporting improvement and development of balance as well as improvement of postural stability of junior alpine skiers (Čillík & Rázusová, 2014; Vitale et al., 2018) but with different methods of balance development on dry-land compared to our intervention methods. Thus, Vitale et al. (2018) suggest that an 8-week intervention in which subjects before activity perform a neuromuscular warm-up succeeds in improving balance. Likewise, Čillík and Rázusová (2014) succeed through a 9-week intervention with specific exercises on rollers to positively influence balance in alpine skiers aged 8 to 10 years. In addition, Slomka et al. (2018) report in their study that a complex balance training program (core stability, plyometrics, balance, and stretching exercises) improves dynamic stability variables in young skiers and results in less low extremity asymmetry.

In their review of balance training programs in athletes, Brachman et al. (2017) report that an effective training balance protocol should last 8 weeks with two training sessions per week, while also stating that authors describe balance performance differently, from proprioceptive training to sensorimotor training and neuromuscular training (Paterno et al., 2004).

Some studies report either that both experimental and control groups show similar improvements, or that there are no improvements in balance performance (Mahieu et al., 2006; Malliou et al., 2006). The natural increase of some variables (SKI IQ) in the control group is also present in our study, but following the intervention protocol, the difference between the pretest and posttest is significantly higher in the experimental group than in the control group in our case.

Although balance ability is a performance factor, there are few studies investigating the effect of balance on alpine skiing and the results are different and controversial. The majority of research focuses on the development of aerobic and anaerobic strength and power (Male et al., 2013; Noe & Paillard, 2005.; Raschner et al., 2012). As a result, practical, applied alpine skiing studies on balance are required.

5. Conclusions

Dry-land training is an important component of a skier's overall training. A significant amount of research has been conducted on the importance of muscular endurance and power, anaerobic and aerobic power, while little research has been conducted on the significance of balance in alpine skiing, and the results have been mixed.

Following the intervention protocol, Ski IQ, which is the power average of the metrics that form it (balance, edging, and pressure), increased more from pretest to posttest in the experimental group, compared to a small, natural increase in the control group. The other metrics that form the SKI IQ show increases in means but they are not statistically significant, a consequence of the relatively small sample.

Our study shows statistically significant improvements in two-legged balance with eyes closed represented by lower values of standard deviation from COP in the antero-posterior and medio-lateral plane, as well as in right-legged balance in the mediolateral plane. These improvements are due to the 9-week balance intervention protocol. As testing apparatus, we used a force plate, for the land tests, force plates being a gold standard in balance measurement. On snow, we used the CARV apparatus, our testing protocol, more rigid due to external factors, a protocol that can be improved with better planning. Nevertheless, Koller and Schobersberger (2019) claim that most preseason fitness tests do not necessarily require the same physiological demands as alpine skiing and that alpine skiing requires largely coordinated eccentric muscular contraction that most fitness tests cannot replicate (Koller & Schobersberger, 2019). For example, aerobic capacity tests do not reliably correlate with performance in alpine ski racing (Neumayr et al., 2003; Nilsson et al., 2018).

Thus, the hypothesis of the preliminary research is partially confirmed: as a result of the intervention we have developed certain sides of balance and improved sports performance represented by SKI IQ. This complex of balance development method can improve certain parameters of the static and dynamic balance of alpine skiers.

Finally, the results of our research support the usefulness of balance development exercises to reduce standard deviations of the center of pressure and to improve dynamic balance during descent (SKI IQ) so that balance is efficiently engaged in descent and falls are prevented.

5.1. Study Limitation

Even though the study met its aims, it had some limitations. One of the limitations was access to a small number of subjects in the snow test (n=20) and the dry-land test (n=24), which limited our ability to draw more conclusive results. Another limitation is the lack of reliability in snow tests, which has not been established in previous studies.

Conflicts of interest

The author(s) declared no potential conflicts of interest.

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