

THE RELATIONSHIP BETWEEN THE FIELD AND THE LABORATORY BALANCE TESTS AND SKIING PERFORMANCE

POVEZANOST TERENSKIH I LABORATORIJSKIH TESTOVA RAVNOTEŽE S USPJEŠNOSTI SKIJAŠA

Lana Ružić¹, Tin Petračić², Ozren Rađenović³

¹Dpt. Sport and Exercise Medicine, Faculty of Kinesiology, University of Zagreb;

²PhD student, Faculty of Kinesiology, University of Zagreb;

³Dpt. of Kinesiology, University of Applied Health Studies, Zagreb

SUMMARY

Well developed proprioceptive abilities are the essential aspects of injury prevention and rehabilitation in many sports including alpine skiing. In our study we hypothesized that the field balance tests might be the factor that influences skier performance. The aim, therefore, was to determine which of the balance tests correlates most closely with skiing performance. The participants were 20 national alpine ski instructor candidates. The study design encompassed 3 simple laboratory balance tests (lateral and front-back tilts tests on the balance board, and hanging board balance test), 2 field balance tests (inner ski jump test and one leg carving test) and 3 official ski elements from Croatian Ski School (short slalom, giant slalom and off piste curves) that require high-level skiing skills. All elements were evaluated by three experienced independent judges. Multiple regression analysis singled out the inner ski jump balance test as the most important prediction factor for alpine skiing performance. We concluded that skiing coaches might find it useful to prescribe more field and specific balance training exercises to high level skiers, especially those which include inner ski jumps.

Key words: alpine skiing, balance, ski instructors

SAŽETAK

Cilj ovog istraživanja bio je utvrditi povezanost između testova ravnoteže na balans daskama i na snijegu te uspješnosti u skijaškim elementima. Hipoteza, koja je bila postavljena prije istraživanja, glasila je da testovi ravnoteže mogu biti čimbenik utjecaja na uspješnost izvedbe skijaških elemenata. Uzorak ispitanika činilo je 20 kandidata za zvanje učitelja skijanja. Mjerni instrumentarij sadržavao je 3 testa ravnoteže na balans daskama, 2 testa ravnoteže na skijaškom terenu te 3 vrlo zahtjevna elementa hrvatske škole skijanja. Svi elementi su bili vrednovani od strane trojice iskusnih sudaca. Rezultati su pokazali da test ravnoteže na skijaškom terenu (skijanje na unutarnjoj skiji) ima najveći utjecaj na izvedbu skijaških elemenata, odnosno na skijašku uspješnost. Temeljem dobivenih rezultata moguće je skijaškim učiteljima i trenerima preporučiti da u svom radu sa skijašima, osobito natjecateljima, posebnu pažnju obrate na testove ravnoteže na skijaškom terenu, čime će doprinijeti većoj uspješnosti svojih skijaša.

Ključne riječi: ravnoteža, učitelji skijanja, alpsko skijanje

INTRODUCTION

Proprioception may be defined as a concept that includes balance and postural control with visual and vestibular contributions, joint kinesthesia, position sense, and muscle reaction time (4). Well developed proprioceptive abilities may be the most essential aspect of injury prevention and rehabilitation in many sports and otherwise (5, 6, 14).

It is known that good agility, a certain level of technical skills, and overall fitness are important in injury prevention among recreational athletes, especially among older, who are more easily injured (9). Research (7) indicates that the balance in alpine skiing is dynamic and tenuous and loss of balance may lead to the accumulation of forces that create severe bending movements at the knee resulting in injury. Injuries in alpine skiing may happen in the specific moment a skier tries to gain back lost balance (15). Group of authors (2) established that 24% of alpine skiing injuries happened due to balance loss. Two factors that could decrease the risk of the aforementioned injuries are better neurophysiological functions (balance) and the development of "smarter" bindings. From the viewpoint of the sports physicians, the athletes with better proprioceptive and balance abilities may perform better and suffer a lower rate of injuries (16). However, we found only one group that investigated the relationship between laboratory balance tests, field balance tests and overall skiing performance. They (11) proved that the indoor balance training on a balance board, which the experimental group underwent while wearing ski boots for 20 min every second day during two weeks of ski school, influenced performance on two downhill ski tests of agility, slalom and snow-ploughing techniques.

Despite the fact that evidence about the influence of balance and proprioception on alpine skiing performance and skiing injuries is very limited, the training of neurophysiological functions (balance, coordination and reaction time) has become an obligatory part of alpine skiers conditioning programme. Probably through empirical observations, many alpine skiing teams have introduced the balance board tests into their training and testing regime (3). In our opinion, there is still a missing link, this being a lack of controlled studies investigating the relationship between laboratory balance tests, field balance tests and overall skiing performance. In our study we hypothesized that field balance tests may be the factors that influence performance in recreational and in competitive skiers. The aim was to determine which of the balance tests correlated most closely with skiing performance.

METHODS

The study design encompassed 3 simple laboratory balance tests ("on the board"), 2 field balance tests ("on the snow") that required advanced skiing skills and 3 official ski elements pertaining to the official Croatian Ski School program. For that reason the subjects were recruited among candidates for national skiing instructors. The sample was comprised of 20 ski instructor candidates (14 male and 6 female) participating in a formation course organized by The Croatian Ski Instructors and Trainers Association in March 2008. Some of the descriptive parameters of the sample are presented in Table 1. All of the candidates passed an admittance test for the ski-instructors course two months prior to the beginning of the study.

Table 1. Average age, number of skiing years and average number of skiing days per year
Tablica 1. Prosječna dob, broj skijaških sezona i dana skijanja u skijaškoj sezoni

	x	s	Minimum	Maximum
Age	27,63	8,06	20,00	45,00
Seasons skied in the past	15,50	7,11	5,00	33,00
Number of skiing days/season	21,75	29,92	5,00	130,00

In order to test the relations between on the board balance tests, on the skis balance tests and ski elements performance the following tests were used:

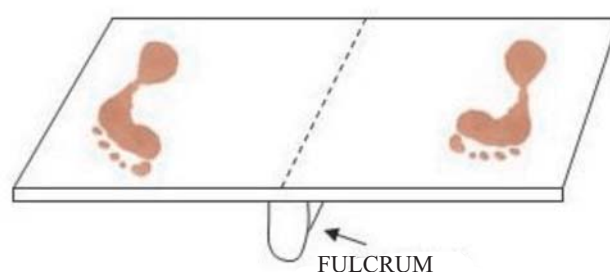
"ON THE BOARD" BALANCE TESTS

Lateral tilts (LAT TILT)

The subject stands on a plywood balance board with feet positioned parallel to the fulcrum (pivot) of the board (Figure 1). The subjects were given a minute to practice before starting the test. Timing begins when the subject is ready and releases his/her hands from the support and stops when either of the later sides of the board touches the ground or the subject hops off or otherwise loses the balance position. The best of three attempts is recorded.

Figure 1. Lateral tilts test

Slika 1. Test bočnog nagnjanja

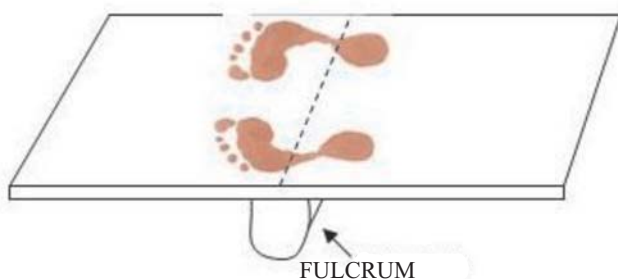


Front-Back tilts (F-B TILT)

The test is performed in the same manner as the lateral tilts test but the subject stands on plywood balance board with feet positioned vertical to the position of the fulcrum (pivot) of the board (Figure 2).

Figure 2. Front-back tilts test

Slika 2. Test naginjanja naprijed nazad

*Hanging board balance test (HANGING BALANCE)*

The hanging board is typically used to improve balance and proprioceptive skills in training or rehabilitation. This is a rectangular platform hanging on a metal frame, 10 cm above the ground. When an unaccustomed person stands on the board it may start to oscillate heavily, eventually leading to the loss of balance. The timing begins when the subject steps on the board and stops when a free leg touches the ground or the person hops off or otherwise loses their balance position. The best of three attempts is recorded.

"ON THE SNOW" FIELD BALANCE TESTS

The two "on the skies" tests were evaluated by three experienced independent judges, all members of the Croatian Ski Instructors and Trainers Association (two being National Ski Demonstrators and one a member of the National Ski Teacher Licensing Committee). The criteria was brought before the beginning of the study. In order to establish the criteria, the three judges performed a pilot testing and evaluation of 10 subjects which were not included in this study.

Inner ski jump test (INNER SKI JUMP)

The test consisted of 8 subsequent curves performed in a way that after every turn the subject skied on the upper ski while the lower leg was lifted up in abduction. At the turn the skier was to shift body weight by jumping on the

inner ski (which soon becomes an upper ski again). Depending on the height of the airborne phase, quality and balance during the landing and ability to balance throughout all turns, performance was evaluated by grades ranging from 5 (excellent) to 1 (poor).

One leg carving turns test (ONE LEG CARV)

During the test the skier performed 20 carving curves on only one, dominant, leg while the other leg was lifted up in abduction. Depending on the ability to lean, tilt, keep the balance and perform rhythmic turns the performance was evaluated by grades ranging from 5 (excellent) to 1 (poor).

SKI ELEMENTS PERFORMANCE

Three "ski elements" performance were evaluated by three experienced independent judges, all members of the Croatian Ski Instructors and Trainers Association (two being National Ski Demonstrators and one a member of the National Ski Teacher Licensing Committee).

Short slalom curves (SHORT SLALOM CURVES)

The element consisted of 20 subsequent short carving curves performed on a steep piste. Depending on the ability to lean, tilt, keep the balance and perform rhythmic turns the performance was evaluated by grades ranging from 5 (excellent) to 1 (poor).

Giant slalom curves (GIANT SLALOM CURVES)

The element consisted of 10 subsequent long carving curves performed on a steeper piste. Depending on the ability to lean, tilt, keep the balance and perform rhythmic turns the performance evaluated by grades ranging from 5 (excellent) to 1 (poor).

Off piste curves (OFF PISTE CURVES)

The element consisted of 15 subsequent long and short carving curves performed on a steeper off piste. Depending on the ability to lean, tilt, keep the balance and perform rhythmic turns the performance evaluated by grades ranging from 5 (excellent) to 1 (poor).

RESULTS

In the beginning we were interested in possible correlations between the "on the board tests", "on the snow tests" and "ski elements performance". The results are presented in Table 2.

The highest correlation found was between the three

Table 2. Correlations (r) between the „on the snow tests“, „on the board tests“ and „ski elements performance“
Tablica 2. Povezanost između testova na snijegu, testova na balans daskama i uspješnosti u skijaškim elementima

	F-B TILTS	LAT TILTS	HANGING BALANCE	INNER SKI JUMP	ONE LEG CARV	SHORT SLALOM CURVES	GIANT SLALOM CURVES	OFF PISTE CURVES
F-B TILTS	1,00	0,00	-0,11	-0,32	-0,14	-0,09	-0,07	0,09
LAT TILTS	0,00	1,00	0,38	0,29	0,18	0,12	0,20	0,09

HANGING BALANCE	-0,11	0,38	1,00	0,15	-0,12	-0,10	0,33	0,01
INNER SKI JUMP	-0,32	0,29	0,15	1,00	0,65*	0,79*	0,64*	0,76*
ONE LEG CARV	-0,14	0,18	-0,12	0,65*	1,00	0,57*	0,33	0,55*
SHORT SLALOM CURVES	-0,09	0,12	-0,10	0,79*	0,57*	1,00	0,80*	0,91*
GIANT SLALOM CURVES	-0,07	0,20	0,33	0,64*	0,33	0,80*	1,00	0,83*
OFF PISTE CURVES	0,09	0,09	0,01	0,76*	0,55*	0,91*	0,83*	1,00

*Marked correlations are significant at $p < 0,05$

ski elements performance, especially between *short slalom curves* and *off piste curves* ($r=0,91$). The *front-back tilts* test, the *lateral tilts* test and *hanging board balance* test showed a zero or a weak correlation with „*on the snow tests*“ and „*ski elements performance*“. The two „*on the snow tests*“ were found to be correlated with each other and with „*ski elements performance*“. The most significant correlation ($r=0,79$) was between *inner ski*

jump and *short slalom curves*.

In order to test the prediction power of „*on the board tests*“ and „*on the snow tests*“ on *short slalom curves* we performed the multiple regression analysis. The model was found to be significant and the variable with the highest and statistically significant prediction power was the *inner ski jump* ($p<0,01$) (Table 3).

The model was tested more through multiple

Table 3. The results of the multiple regression analysis for *Short slalom curves*

Tablica 3. Rezultati multiple regresije za *Brzo vijuganje*

Regression Summary for Dependent Variable: Short slalom curves R= ,8341 R ² = ,6958 Adjusted R ² = ,5871 F(5,14)=6,4039						
	Beta	Std.Err.	B	Std.Err.	t(14)	p-level
Intercept			1,05	0,50	2,09	0,05
F-B TILTS	0,18	0,16	0,00	0,00	1,13	0,28
LAT TILTS	-0,06	0,17	-0,00	0,01	-0,38	0,71
HANGING BALANCE	-0,18	0,17	-0,01	0,01	-1,08	0,29
INNER SKI JUMP	0,88	0,22	0,71	0,17	4,11	0,00
ONE LEG CARV	0,01	0,21	0,01	0,19	0,04	0,97

regression analysis for *giant slalom curves*. The only „*on the snow test*“ that was found to be a significant predictor was again the *inner ski jump* (Table 4) but with lower

prediction power ($p<0,02$) than for the *short slalom curves*.

The model was tested once more through multiple

Table 4. The results of the multiple regression analysis for *Giant slalom curves*

Tablica 4. Rezultati multiple regresije za *Paralelni dinamični zavoj*

Regression Summary for Dependent Variable: Giant slalom curves R= ,7070 R ² = ,4999 Adjusted R ² = ,3213 F(5,14)=2,7990						
	Beta	Std.Err.	B	Std.Err.	t(14)	p-level
Intercept			0,83	0,66	1,26	0,23
F-B TILTS	0,19	0,20	0,00	0,00	0,94	0,36
LAT TILTS	-0,10	0,21	-0,00	0,01	-0,48	0,64
HANGING BALANCE	0,27	0,22	0,01	0,01	1,27	0,23
INNER SKI JUMP	0,73	0,28	0,60	0,23	2,65	0,02
ONE LEG CARV	-0,07	0,26	-0,06	0,25	-0,25	0,81

regression analysis for *off piste curves*. The tests that were found to be significant predictors for *off piste curves* were once again the *inner ski jump* ($p < 0,01$) and the *front-back*

tilts test (F-B TILTS) ($p < 0,03$) (Table 5).

DISCUSSION

Table 5. The results of the multiple regression analysis for *Off piste curves*
Tablica 5. Rezultati multiple regresije za *Terensku vožnju*

Regression Summary for Dependent Variable: Off piste curves R= ,8546 R2= ,7303 Adjusted R2= ,6339 F(5,14)=7,5808						
	Beta	Std.Err.	B	Std.Err.	t(14)	p-level
Intercept			0,53	0,49	1,09	0,29
F-B TILTS	0,39	0,15	0,00	0,00	2,62	0,02
LAT TILTS	-0,16	0,16	-0,01	0,01	-1,04	0,31
HANGING BALANCE	-0,02	0,16	-0,0	0,01	-0,12	0,90
INNER SKI JUMP	0,91	0,20	0,76	0,17	4,51	0,00
ONE LEG CARV	0,03	0,19	0,03	0,19	0,16	0,87

We hypothesized that field balance tests may be the factors that influence performance in recreational and competitive skiers. The primary finding of this study was that the field balance test known as the inner ski jump singled out as the most important prediction factor for alpine skiing performance. This study confirmed the previously published data (11) about the importance of balance tests for skiing performance. Balance is defined as the process of maintaining center of gravity over the base of support. Factors that influence balance include sensory information obtained from the somatosensory, visual and vestibular systems and motor responses that affect coordination, joint range of motion (ROM) and strength (12). Some evidence in the literature suggests that superior balance among experienced athletes is largely the result of repetitive training experiences that influence motor responses and not greater sensitivity of the vestibular system (1).

Group of researchers (13) showed that the battery of tests (aerobic capacity, balance, jumping, isokinetic core power, isokinetic leg power, isometric bench press, isometric bench pull, snowboard start simulator) explained between 61 and 98% of variance when predicting snowboard performance.

In skiing there is principally no difference between the operating mechanism of a ski-racer and a skier who masters the technique of carving – both try to ski with as little sliding as possible (8).

The reasons why inner ski jump had the highest and statistically significant prediction power on short slalom curves may be found in the fact that high-level skiers must have excellent balance on both skies when they are making short slalom curves, so if they are able to make an inner ski jump very well and put balance just on the inner ski, which is more difficult than on the outside ski, they have very big potential of making short slalom curves very well. Also, many elite skiers in The World Cup quite often make the jumps on the inner ski after the gates and make the first contact with the snow with an upper edge of the inner ski. That may be the reason the inner ski jump had the predictive value for other skiing performances. High-

level skiers often put much more balance on the upper edge of the inner ski in those curves than was used before when the technique was different. Also, a lifted outside ski when entering the gates during the GS is not an unusual thing to see during World Cup races. Results showed also that the inner ski jump was found to be a significant predictor for off-piste curves and it is known that off piste curves are a mix of short and long curves on unprepared terrain where skiers often lose balance and must be able to ski just on the upper edge of the inner ski.

According to (7) the balance in alpine skiing is dynamic and tenuous and loss of balance may lead to the accumulation of forces that create severe bending movements at the knee resulting in injury. Well developed proprioceptive abilities may be essential aspects of injury prevention and rehabilitation in many sports and otherwise (5, 6, 14). That is why we thought that skiing on only one leg might be an important predictive factor for success in other skiing elements. However, we found no significant relationship between the second field balance test - one leg carving and skiing performance. This is probably due to the fact that skiing on only one leg requires using both edges (inner and outer edge of only one ski) in the same manner, which is usually not the case in normal skiing.

The limitation of this study lies in the fact that the subjects were all skilled skiers because we observed balance scores among ski instructors candidates. These findings may be valuable for skiing coaches who might find it useful to prescribe more field balance training to high-level skiers, especially those which include inner ski jumps. This is not to say that other balance exercises (off the snow) would not contribute to the performance enhancement but it seems that on-the-snow balance exercises seem to be of benefit to the high-level skiers.

CONCLUSIONS

“On the skies“ balance tests, especially inner ski jump test might be a very useful indicator for “ski elements” performance. The application of an on-the-snow balance training program could improve body

control and proprioception in high level skiers, reduce the risk of injuries and improve performance. Nevertheless, it is important to understand that only specific balance training (and tests) is correlated to alpine skiing performance.

Acknowledgements

We thank the Croatian Ski Instructors and Trainers Association, and the president Dag Modric, prof., for all their help and collaboration.

References

1. Balter SGT, Stokroos RJ, Akkermans E, Kingma H. Habituation to galvanic vestibular stimulation for analysis of postural control abilities in gymnasts. *Neurosci Lett*. 2004; 366: 71-5.
2. Bouter LM, Knipschild PG, Volovics A. Personal and environmental factors in relation to injury risk in downhill skiing. *Int J Sports Med* 1989; 10: 298-301.
3. Ellis D, Sparovec J. Canadian alpine ski team testing protocol. Available online at <http://www.nb.alpine.nb.ca> (Accessed 24 March 2008).
4. Ergen E, Ulkar B. Proprioception and ankle injuries in soccer. *Clin J Sport Med* 2008; 27: 195-217.
5. Fitzgerald GK, Axe MJ, Snyder-Mackler L. The efficacy of perturbation training in nonoperative anterior cruciate ligament rehabilitation programs for physical active individuals. *Phys Ther*. 2000; 80: 128-40.
6. Gerritsen KG, Nachbauer W, van den Bogert AJ. Computer simulation of landing movement in downhill skiing: anterior cruciate ligament injuries. *J Biomech* 1996; 29: 845-54.
7. Johnson SC. Anterior cruciate ligament injury in elite Alpine competitors. *Med Sci Sports Exerc* 1995; 27: 323-7.
8. Kaiser F. Carving in comparison with ski technique of the skiing athlete (competitive skier) and the leisure and comfort level skier. *Sportverletz Sportschaden* 1997; 11: 126-8.
9. Kallinen M, Markku A. Aging, physical activity and sports injuries. An overview of common sports injuries in the elderly. *Sports Med*, 1995; 20: 41-52.
10. Malliou P, Amoutzas K, Theodosiou A, Gioftsidou A, Mantis K, Pylianidis T, White AT, Johnson SC. Physiological aspects and injury in elite Alpine skiers. *Sports Med*, 1993; 15: 170-8.
11. Malliou P, Amoutzas K, Theodosiou A, Gioftsidou A, Mantis K, Pylianidis T, Kioumourtzoglou E. Proprioceptive training for learning downhill skiing. *Percept Mot Skills*, 2004; 99: 149-54.
12. Palmieri RM, Ingersoll CD, Stone MB, Krause BA. Center-of-pressure parameters used in the assessment of postural control. *J Sport Rehabil*. 2002; 11: 51-66.
13. Platzer HP, Raschner C, Patterson C, Lember S. Comparison of physical characteristics and performance among elite snowboarders. *Journal of Strength and Conditioning Research* 2009; 23: 1427-32.
14. Taube W, Kullmann N, Leukel C, Kurz O, Amtage F, Gollhofer A. Differential reflex adaptations following sensorimotor and strength training in young elite athletes. *Int J Sports Med* 2007; 28: 999-1005.
15. Tudor A, Sestan B, Nemec B, Prpic T, Rubinic D. Intra-articular calcaneal fracture in a 14-year-old competing skier: case report. *Croatian Medical Journal* 2003; 44: 764-6.
16. White AT, Johnson SC. Physiological aspects and injury in elite Alpine skiers. *Sports Med*, 1993; 15: 170-8.