DEVELOPMENT OF THE SKIING SPECIFIC DYNAMIC BALANCE TEST

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ABSTRACT

The aim of this report is to present the newly developed skiing specific dynamic balance test and the effect of additional weight bearing on the observed parameters. The test is based on the quantification of precision with which a skier is able to track the predefined dynamics of shifting his/her centre-of-pressure. The task is visual feed-back driven and combines the reference curve and the real-time signal from the force plate. Subject sample included 12 professional Slovene skiers. Each subject underwent a set of three tests (without, half and full body additional weight). High repeatability of the analyzed parameters was observed. A statistically significant effect of the additional loading was present and the mechanisms behind it will be discussed.

Key words: alpine skiing, dynamic balance, testing, assessment

INTRODUCTION

Balance is fundamental for human movement. Maintaining balance during anti-gravitational activities, as well as proper body posture, represent a ground-stone for the execution of other secondary movements. The latter are used to propel ourselves through the space or to manipulate with the objects in the surrounding environment (Winter, 1995). The importance of balance can be demonstrated with two extreme examples; increased risk of falling in elderly because of the diminished balance and the requirement for extremely good dynamic balance in alpine skiers to complete their race successfully. When balance is lost, the risk of falling is increased (Baczkowicz, Szczegielniak, & Proszkowiec, 2008). Falls represent one of the most serious health problems in elderly populations. Poor balance has been shown to be affected by different pathologies and can even be their origin (de Noronha, Refshauge, Herbert, Kilbreath, & Hertel, 2006). On the other hand superior athletic skill demands good balance as well. Not only that of a skier, but also other athletes` performances depend greatly on balance. However, balance demands are specific to different sport disciplines.

Balance can be mechanically defined as the ability to sustain the centre of body mass above the limits of the support surface (Sarabon, Rosker, Loefler, & Kern, 2010), where support surface is defined as the area between the feet. When these demands are not met anymore, body starts to fall. Human body uses different strategies to maintain balance. The two most general one are ankle and hip strategies (Winter, Patla, Prince, Ishac, & Gielo-Perczak, 1998; Winter, 1995). The first strategy is usually used to compensate rotational or smaller perturbations, while the second one is used when the support surface translates, or when the perturbation to balance is bigger. Both strategies are very important when we talk about dynamic body balance.

Alpine skiing is physically very demanding sport discipline in which power, strength endurance, balance, and coordination are combined in a complex cyclic pattern. A skier is only able to concentrate on tactics and movement precision if the basic requirements are assured. Physical conditioning of the alpine skier should therefore focus on choosing those exercises which combine endurance in strength and balance. This is namely the situation to which skiers will be exposed on the ski slope. Namely, if the skier is not well trained in this way, such kind of loading will result in local acidosis, loss of balance and finally decay of technique.

Regarding balance of skiers, studies of effect of ski boots have been conducted. Noe, Amarantini and Paillard (2009) showed that in experienced skiers wearing ski boots has no effect the dynamic balance as measured by the movable platform. Opposite to that, other researchers (Mildner, Lembert, & Raschner, 2010; Noe and Paillard (2005)) reported about significantly better results achieved barefoot as compared to the ski boots conditions, thereby using a similar testing procedure. The purpose of this experiment was to present newly developed skiing specific test and to check its intra-session repeatability and sensitivity to the acute manipulation of applying an additional strength demand to the dynamic balance task. The developed balance test turned out to be a useful assessment tool that allows a great level of individualization.

METHODS

Twelve healthy male professional Slovene skiers between 16 and 25 years of age participated in the study. Participants gave their written consent to participate in the study. All procedures conformed to the 1964 Declaration of Helsinki and were approved by the Committee for Medical Ethics at the Ministry of Health (Slovenia). Before performing tests the whole procedure was presented in details to each subject separately.

The experiment was based on the newly developed skiing specific dynamic balance test. The test was based on a tracking of predefined dynamics of shifting of COP in the medio-lateral direction. The predefined dynamics was defined with pseudorandom trajectory (reference trajectory) that was composed of several segments; each one was an average of three sine signals with frequency and amplitude in the predefined amplitude range. The reference trajectory was scaled to 70% of the maximum amplitude in medio-lateral direction for each subject. The reference trajectory and real-time COP in medio-lateral direction were projected in real-time on a wall in front of the subject (Figure 1). The projected field of view took ten seconds of the trajectories, where the first five seconds were both trajectories and the last five seconds was only reference trajectory. Field of view was updated ten times per second, thus the subject had no difficulties tracking the reference trajectory.

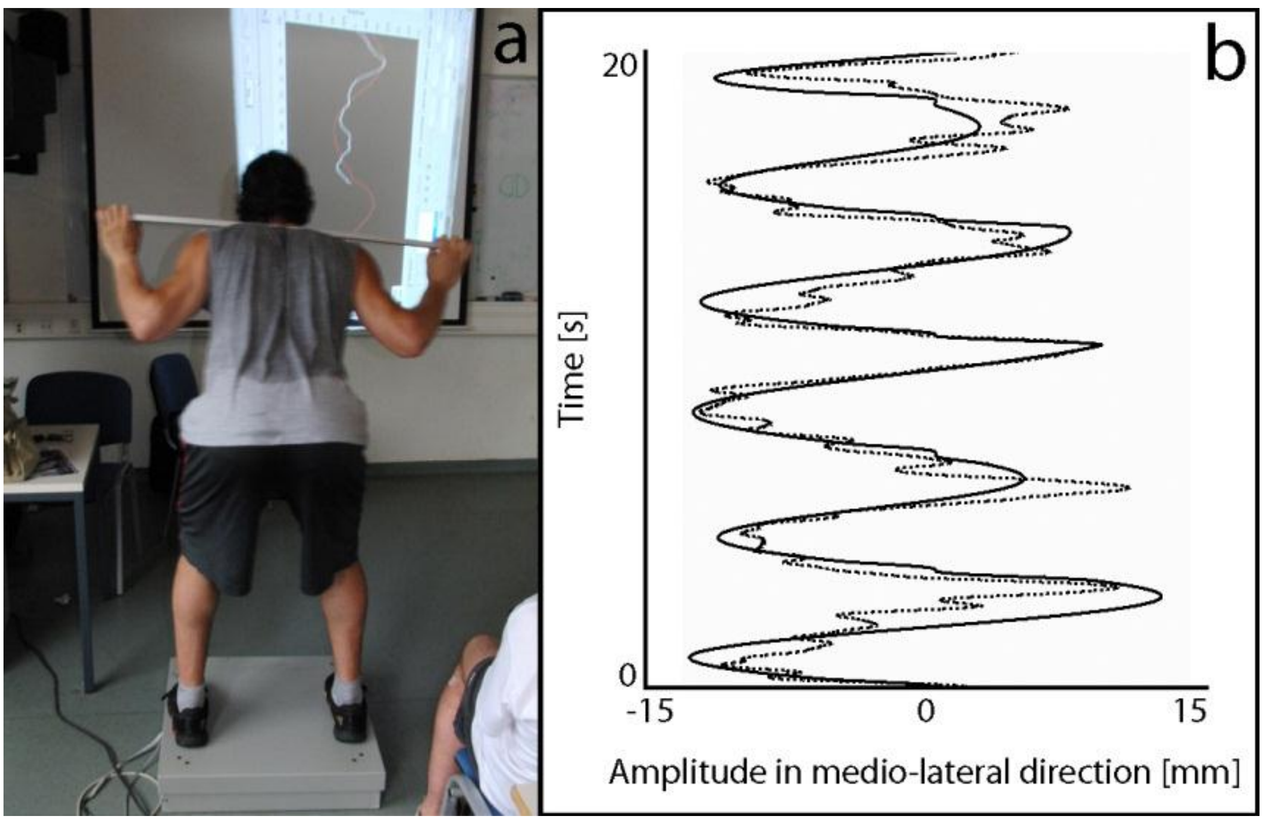

Figure 1. (a) A subject during measurement. (b) Projection of the reference trajectory and real-time COP in medio-lateral direction.

Each subject underwent a set of three tests with different levels of difficulty regarding loading with additional weights put on the shoulder. All three tests were parallel stance (PS) with active position in knees (~30° flexion), arms on a bar, which was placed on the shoulders, and view directed at the projection in front of the subject. Before the measurements began the subject was exposed to a standard accommodation protocol to become familiar with the movement task. First test was carried out with no additional weights but imitating the hands position using a wooden stick (NAW). The second test was performed with the additional weight equal to half body weight (HAW), while during the third test the subject was holding the additional weight equal to one body weight (FAW). Each subject performed tree repetitions of each test (nine repetitions altogether) in random order to eliminate the effect of influence between tests. Each repetition took 60 seconds with at least 120 seconds rest intervals between trials. Subjects were asked to track reference trajectory as precisely as possible.

The experiment was carried out with an AMTI force plate that can provide the information about the projection of COP. Signals were acquired with a standard personal computer at sampling rate of 1000 Hz. Pre-processing of signals consisted of filtering the signals with the band-pass Butterworth filter (low cut-off frequency was 0.1 Hz, high cut-off frequency was 20Hz and order was 2). Custom made software used for the acquisition of the signals from force plate, making reference trajectory, projection on the wall and the analysis was developed in LabVIEW 2010. Statistical analyses were made with SPSS PASW Statistics 18 software and Spreadsheet for Calculating Reliability ("New View of Statistics: Reliability Calculations," n.d.). Reliability was assessed for the first test (NAW). Mean values (MV) and standard deviations (SD) of each trial and all trials together, minimum value, maximal value, typical error (TE) and coefficient of variation (CV%) were calculated with Spreadsheet for Calculating Reliability. Single (ICCs) and average (ICCa) intra-class correlation coefficients (two-way random model and absolute agreement type) were calculated with SPSS. Statistically significant differences across all tests were tested with one-way repeated measures ANOVA (RANOVA), while between tests differences were tested with post-hoc pairwise t-test analyses.

Precision of tracking the reference trajectory was quantified with the following nine parameters: mean amplitude between trajectories (MA), area between trajectories (ABT), normalized error (NE), mean frequency (MF), number of zero crossings (NOZC), time driven on left side (TDL), time driven on right side (TDR), normalized error on left side (NEL), normalized error on right side (NER). Normalized error was calculated as $sqrt(\sum((R-M)^2/{M_{amp}}^2)/T)$, where R is real-time COP trajectory in medio-lateral direction, M is reference trajectory, M_{amp} is maximal amplitude of reference trajectory and T is duration.

RESULTS

ICCa coefficients were high repeatable (ICCa > 0.8) for all parameters, except for NOZC ICCa was 0.74. The highest ICCa and ICCs were observed for NER parameter (0.90 and 0.88 respectively), followed closely by MA, ABT and NE. CV% was the lowest for TDL and the highest for NOZC. All results of repeatability analysis are presented in Table 1.

Parameter	Trial 1	Trial 2	Trial 3	Mean score	Range	TE	CV%	ICCs	ICCa
MA [m]	38.93 ± 13.37	35.72 ± 12.00	33.56 ± 7.63	36.07 ± 11.27	19.33 - 85.76	4.78	13.26	0.72	0.89
ABT [m*s]	1.95 ± 0.67	1.79 ± 0.60	1.68 ± 0.38	1.80 ± 0.56	0.97 - 4.29	0.24	13.26	0.72	0.89
NE	5.31 ± 1.85	4.91 ± 1.66	4.67 ± 1.04	4.96 ± 1.56	2.83 - 12.31	0.65	13.03	0.73	0.89
MF [Hz]	0.37 ± 0.08	0.38 ± 0.06	0.37 ± 0.07	0.37 ± 0.07	0.23 - 0.55	0.04	9.45	0.72	0.88
NOZC	79.33 ± 29.36	83.46 ± 34.67	89.79 ± 26.51	84.19 ± 30.37	41.00 - 175.00	22.19	26.35	0.48	0.74
TDL [%]	0.56 ± 0.05	0.55 ± 0.07	0.56 ± 0.07	0.56 ± 0.07	0.40 - 0.70	0.04	7.24	0.68	0.86
TDR [%]	0.44 ± 0.05	0.45 ± 0.07	0.44 ± 0.07	0.44 ± 0.07	0.30 - 0.60	0.04	9.03	0.68	0.86
NEL	3.87 ± 1.39	3.62 ± 1.26	3.42 ± 0.92	3.64 ± 1.21	1.90 - 8.53	0.61	16.86	0.66	0.85
NER	3.59 ± 1.38	3.25 ± 1.26	3.10 ± 0.86	3.31 ± 1.19	2.09 - 8.87	0.50	15.13	0.75	0.90

Table 1. Results of repeatability analysis for PS. For Trial 1, Trial 2, Trial 3 and Mean score fields contain mean value ± standard deviation; Range fields contains minimum – maximum values.

Statistically significant differences ($p < 0.05$) across all three levels of difficulty were observed for MA, ABT, NE, MF, NOZC, NEL and NER; while TDL and TDR were not statistically significantly different. Statistically significant differences between NAW-to-HAW and NAW-to-FAW were detected for the same parameters; for all but for NOZC. Statistically significant differences between HAW and FAW were observed only for NOZC among all the parameters. More detailed results are shown in Table 2.

Parameter	RANOVA	Pairwise t-tests		
		NAW – HAW	NAW – FAW	HAW – FAW
MA [m]	***	**	**	NS
ABT [m*s]	***	**	**	NS
NE	***	**	**	NS
MF [Hz]	**	**	**	NS
NOZC	***	NS	***	***
TDL [%]	NS	NS	NS	NS
TDR [%]	NS	NS	NS	NS
NEL	***	**	**	NS
NER	**	*	*	NS

*Table 2. Differences between tasks. NS – not significant, * – p < 0.05, ** – p < 0.01 and *** – p < 0.001.*

DISCUSSION

Repeatability and sensitivity are two of the basic metric characteristics of each test and should be evaluated when a new test is proposed. Therefore, we wanted to test them after the development of the new technology and concept of the skiing specific balance test was completed. The movement task used in the dynamic balance test is based on actively shifting body weight from one leg to the other so that the COP follows the predefined randomized trajectory, that is fed-back to the subject in real time, as closely as possible. Nine quantitative parameters are calculated from the acquired trajectory. Results of our study showed that eight of these parameters have high repeatability (ICCa ≥ 0.85). Moderate level of repeatability was observed in NOZC (ICCa =0.74), that had also the highest CV% (26%). On the other hand, majority of the other parameters showed CV% ≤ 15%. Based on these results we can conclude that the developed balance test and its parameterization have high level of repeatability when the average of three 60-second repetitions is used. However, the repeatability characteristics drop considerably if only one testing trial is used in the evaluation (all ICCs ≤ 0.75). We can conclude that administration of the three-repetition measurement protocol (3 x 60 s), with two to three shorter (30 s) customization trials, should be proposed for further use. Based on practical observations during our experiment we need to stress the importance of using adequate (≥ 2 min) rest intervals between trials to avoid fatigue.

The subjects participating in our study were top trained individuals, all of them being members of different selections of the national alpine skiing teams. Technical requirements of alpine skiing include constant voluntary weight above the support surface in different directions, predominantly in the frontal plane of the body. These side-to-side transitions are combined with high compression forces, which is why strength-balance combination needs to be in the centre of attention of physical conditioning programs in alpine skiing. In order to evaluate this specific functional ability we need to have the test which is enough demanding and can be up-graded by the use of free weights. Additionally, it is important that the test is sensitive enough to detect differences (i) between skiers of unequal level of sport specific fitness, (ii) resulting from acute manipulations such as fatigue, potentiation or adding an additional mental or physical load, (iii) that come as a result of the conditioning or deconditioning, etc. In our study we tested the mean differences in the analysed parameters among the dynamic balance task of three different levels of pretentiousness – no additional load, moderate additional load, and high additional load. With this kind of manipulations of the basic task we evoked acute changes in the observed parameters. Majority of the parameters turned out to be sensitive to detect differences between different levels of the task difficulties. However, probably because of the specific sample of subjects, the differences in the balance parameters reached statistically significant levels for comparisons between the task with no additional weight and the other two tasks with additional weights. HAW-to-FAW comparisons did not reach the level of statistical significance in any of the parameters except in NOZC. Only TDL and TDR among all parameters did not reach statistically significant levels for any comparison between tasks.

If we conclude, we can say that additional inertial load significantly influences the dynamic balance regulation in alpine skiers. However, loads of up to one additional body weight seems to be too small to enable further insight into the balance-strength interplay. This was most probably because of the fact that FAW was still far from the level of the load that would result in fatigue and decreased neuromuscular control. In our future studies, we will address this question and proceed with the study where we will use higher loads or a post-fatigue study protocol.

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