

# EVALUATION OF THE DYNAMIC BALANCE TRACKING TEST

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## Introduction

Several balance tests have been developed and used in everyday clinical practice as well as in laboratory measurements<sup>1,2</sup>. Both, assessments of static and dynamic balance have been addressed, but, most often these tests turned out to have good sensitivity and reliability in patient population<sup>3</sup>, while they showed several limitations for their use in athletes<sup>1</sup>.

Among many other, three main types of conceptually different dynamic balance tasks have been studied in the past: (1) tasks in which a subject is voluntarily shifting the centre of body mass above the stable support surface<sup>4</sup>, (2) tasks in which a subject attempts to sustain balance position on an inherently unstable support surface<sup>5</sup>, and (3) tasks which involve locomotion activities<sup>6</sup>. The biomechanical and motor control foundation of these tests is often much different from the requirements of a specific sport. In order to overcome these drawbacks we developed a dynamic balance test that would be appropriate for use in well trained individuals (e.g. alpine skiers). This test involves voluntary shifting of the centre of foot pressure (COP) on the support surface, thereby trying to follow the pre-defined COP movement dynamics. The rationale for this test was adopted from the active tracking tests which have been used previously only on open kinetic chain tasks<sup>7,8</sup>.

The aim of this study was to evaluate a newly developed dynamic balance test which is based on active COP tracking task. We evaluated intra-session repeatability of the test as well as its sensitivity to detect differences: (1) between two groups of subjects with different dynamic balance training history and (2) among different levels of the task difficulty, which was achieved by applying additional loads on subject's shoulders.

## Methods

- Experimental group (EG): 12 male pro skiers (trained in dynamic balance; age  $19.8 \pm 2.7$  yrs, height  $181.5 \pm 5.1$  cm, weight  $83.9 \pm 8.1$  kg).
- Control group (CG): 12 normal subjects (not trained in dynamic balance; age  $22.3 \pm 3.7$  yrs, height  $169.7 \pm 11.2$  cm, weight  $66.4 \pm 13.6$  kg).
- EG performed three tests with different levels of difficulty (no additional weights (NAW), additional weight equal to half body weight (HAW) and additional weight equal to full body weight (FAW)).
- CG performed only NAW task.
- Three 30 s repetitions of each test with 120 s rest intervals between trials.
- The test was based on tracking of predefined dynamics (reference trajectory) with shifting COP in the medio-lateral direction (Figure 1).
- The reference trajectory and COP were projected in real-time (time window 10 s, update rate 10 Hz) in front of the subject.
- The following dependent variables were calculated: Mean absolute error (TE), standard deviation of absolute error (SDAE), root mean squared error (RMSE), area between trajectories (A), normalized error (NE), mean frequency (MF), median frequency (MEF), peak frequency (PF), 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) and cross correlation (CC).
- Single (ICCs) and average (ICCa) intra-class correlation coefficient, typical error (TE) and coefficient of variation (CV%).
- One-way repeated measures ANOVA (RANOVA); post hoc t-test for dependent samples to test the difference across the levels of difficulty.
- T-test for independent samples to test the difference between the two groups.

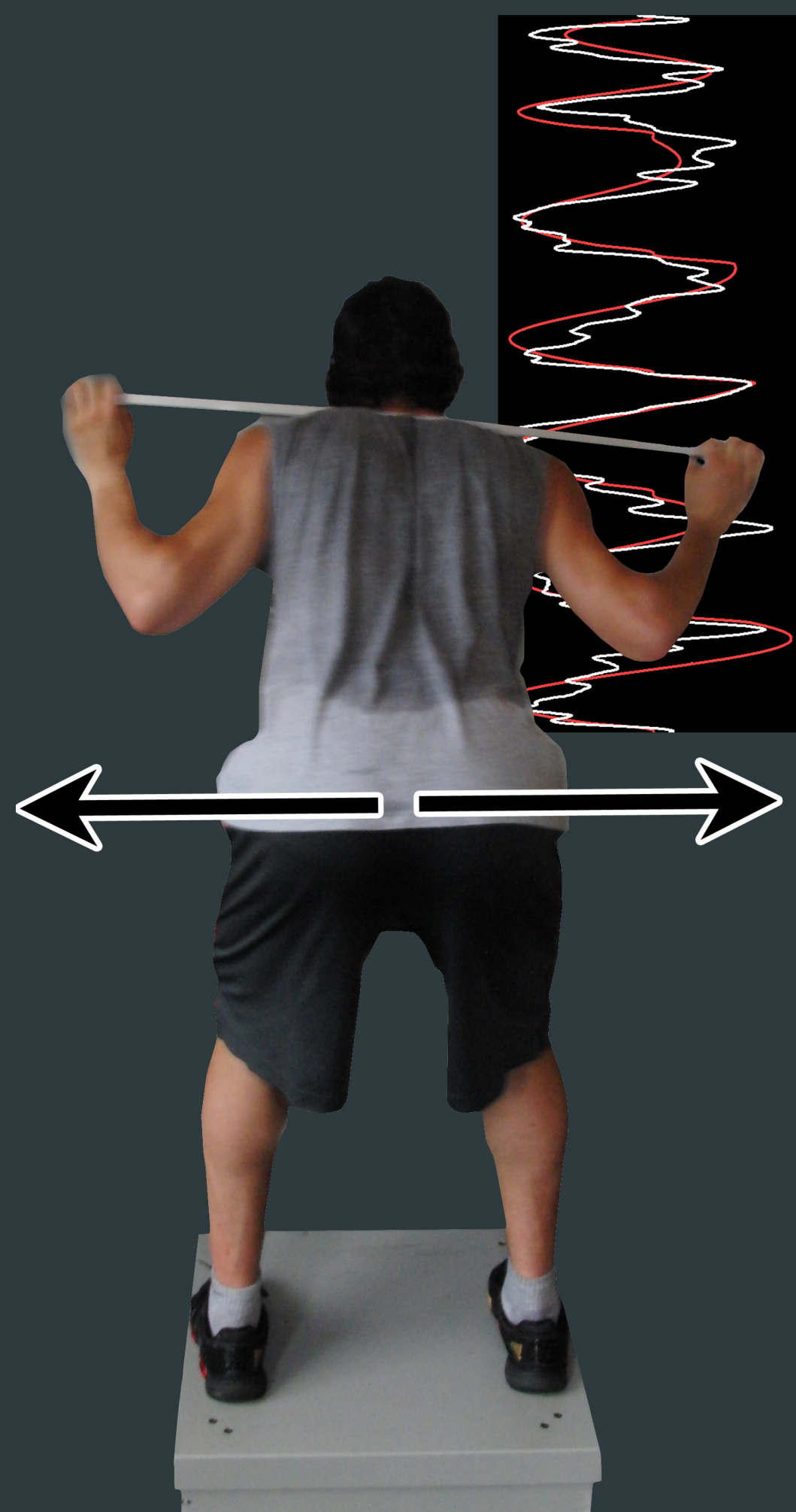


Figure 1. Measurement setup.

## Results

Parameter	TE	CV%	ICCs	ICCa
MAE	0.0052	12.79 (10.40 - 16.62)	0.677 (0.461 - 0.833)	0.863 (0.719 - 0.937)
SDAE	0.0042	14.17 (11.52 - 18.40)	0.639 (0.423 - 0.807)	0.842 (0.687 - 0.926)
RMSE	0.0064	12.59 (10.24 - 16.35)	0.672 (0.457 - 0.829)	0.860 (0.716 - 0.936)
A	0.16	12.79 (10.40 - 16.62)	0.677 (0.461 - 0.833)	0.863 (0.719 - 0.937)
NE	0.78	11.89 (9.67 - 15.44)	0.772 (0.588 - 0.888)	0.910 (0.811 - 0.960)
MF	0.052	14.96 (12.16 - 19.43)	0.766 (0.600 - 0.881)	0.908 (0.818 - 0.957)
MEF	0.084	34.42 (27.99 - 44.72)	0.536 (0.295 - 0.742)	0.776 (0.557 - 0.896)
PF	0.11	55.13 (44.83 - 71.61)	0.251 (-0.001 - 0.528)	0.501 (-0.002 - 0.770)
NOZC	17.05	34.80 (28.30 - 45.20)	0.484 (0.236 - 0.707)	0.738 (0.481 - 0.879)
TDL	0.04	7.11 (5.78 - 9.24)	0.823 (0.688 - 0.912)	0.933 (0.869 - 0.969)
TDR	0.04	9.34 (7.59 - 12.13)	0.823 (0.688 - 0.912)	0.933 (0.869 - 0.969)
NEL	0.75	14.87 (12.09 - 19.32)	0.772 (0.594 - 0.887)	0.911 (0.814 - 0.959)
NER	0.67	16.43 (13.36 - 21.35)	0.736 (0.545 - 0.867)	0.893 (0.782 - 0.951)
CC	0.076	11.08 (9.01 - 14.40)	0.768 (0.576 - 0.887)	0.909 (0.803 - 0.959)

Table 1. Results of repeatability analysis. CV%, ICCs, ICCa fields contain value (confidence interval).

Parameter	Additional load differences				Differences between the groups t-test for independent samples
	RANOVA	t-test for dependent samples			
		NAW-HAW	NAW-FAW	HAW-FAW	
MAE	***	***	**	***	NS
SDAE	***	*	**	**	NS
RMSE	***	***	***	**	NS
A	***	***	***	**	NS
NE	***	***	***	**	**
MF	***	***	***	*	NS
MEF	NS	NS	NS	*	NS
PF	NS	NS	NS	NS	NS
NOZC	**	NS	**	**	**
TDL	NS	NS	NS	NS	NS
TDR	NS	NS	NS	NS	NS
NEL	**	**	**	NS	***
NER	**	*	**	NS	NS
CC	**	**	**	NS	**

Table 2. Additional load differences and differences between the groups. NS – not significant, \* –  $p < 0.05$ , \*\* –  $p < 0.01$  and \*\*\* –  $p < 0.001$ .

## Discussion

The developed dynamic balance tracing test was adopted from hand grip and position tracking tasks originating from motor control studies<sup>9,10</sup>. Parameters that evaluate performance based on relative or normalized deviations (NE and CC) showed the best intra-session repeatability and were at the same time the most, thus able to distinguish between different levels of the task difficulty as well as between the EG and CG. Parameters that evaluate performance based on absolute deviations had high repeatability and were able to distinguish between different levels of difficulty, but not between the EG and CG. Parameters that examine performance based on the side (left or right) of the reference trajectory (TDL, TDR, NEL and NER) should not be used for sensitivity analysis, but due to their very high repeatability can be used to describe some specific dynamic balance behaviours of the subject, such as side-to-side ratio or similar. In conclusion, we can say that the presented COP tracking test with its described parameters is suitable for the evaluation of dynamic balance in healthy people. All highly repeatable parameters are appropriate for the interpretation of results, but one has to be very careful to use them for the right purpose. CC and NE seem to be the most suitable for practical use. In our future studies, we are going to address inter-session repeatability and the influence of fatigue on tracking ability.

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