Measurement 85 (2016) 13–19

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Reliability and sensitivity of a novel dynamic balance test for alpine skiers

Andrej Panjan [a,1], Matej Supej [b,2], Jernej Rosker [a,c,d,3], Nejc Sarabon [a,c,d,*]

[a] S2P Ltd., Laboratory for Motor Control and Motor Behaviour, Ljubljana, Slovenia
[b] University of Ljubljana, Faculty of Sport, Laboratory for Biomechanics, Ljubljana, Slovenia
[c] University of Primorska, Faculty of Mathematics, Natural Sciences and Information Technologies, Koper, Slovenia
[d] University of Primorska, Andrej Marusic Institute, Department of Health Studies, Koper, Slovenia

A R T I C L E   I N F O

Article history:
Received 29 November 2015
Received in revised form 9 February 2016
Accepted 10 February 2016
Available online 16 February 2016

Keywords:
Alpine skiing
Body sway
Posture
Additional load

A B S T R A C T

Goal of this study was to present a new alpine skiing specific dynamic balance test and assess its reliability and sensitivity. Twelve trained and twenty-two non-trained skiers participated in the study. Both groups performed a dynamic lateral weight shift task in a semi-squat position, pursuing a predefined trajectory with their centre of pressure. The task was done without and with two different additional loads. Inter-session reliability was assessed only for the non-trained gorup. The alpine specific balance test proved to have moderate reliability and was sensitive to the training status as well as to the different weight conditions. This study showed that new alpine specific balance test is reliable and sensitive to the expert level of skiing and training status.

1. Introduction

A good balance is believed to be important for recreational and competitive alpine skiing performance [1]. In general, superior balance has been shown to be an important injury prevention factor in different sports [2,3] but its relation to athletic and specifically to alpine skiing performance has not been well studied [1,4]. Poor balance could affect biomechanical factors that determine skiing velocity such as smooth application of ground reaction force during a turn [5,6]. More specifically, loss of balance during a turn might initiate compensatory body movements, causing late initiation of the turn, less controlled force production, longer turns and last but not least use of a sliding technique in order to ski through the gate.

Studies dealing with balance in alpine skiers are contradictory to above generally accepted ideas, suggesting that international-competitive skiers have similar or even inferior static and dynamic balance as compared to their recreational peers [4]. Such contradicting results can be due to the unspecific and undemanding balance tests used in these studies [7,8]. An attempt to introduce alpine specific demands to balance testing was presented in the study done by Noe et al. [9]. Their results indicated, that by wearing skiing boots the balancing strategy changed from more ankle to more hip involved. In addition, the study showed

Abbreviations: ICC, intra-class correlation coefficient; TS, trained skiers; NS, non-trained skiers; CoP, centre of pressure; NAW, no additional weight; HAW, added load equivalent to half body weight; FAW, load equivelent to one body weight; NE, normalized error; CC, cross correlation; WNE, weighed normalized error; TE, typical error; CV%, coefficient of variation; ICCs, single intra-class correlation coefficient; ICCa, average intra-class correlation coefficient; RANOVA, repeated-measured analysis of variance; ANCOVA, analysis of covariance.

* Corresponding author at: Muzejski trg 2, SI-6000 Koper, Slovenia. Tel.: +386 40 429 505.

E-mail addresses: andrej.panjan@s2p.si (A. Panjan), matej.supej@fsp.uni-lj.si (M. Supej), jernej.rosker@gmail.com (J. Rosker), nejc.sarabon@iam.upr.si (N. Sarabon).

[1] Address: Tehnoloski park 19, SI-1000 Ljubljana, Slovenia. Tel.: +386 31 245 205.

[2] Address: Gortanova 22, SI-1000 Ljubljana, Slovenia. Tel.: +386 1 520 77 62.

[3] Address: Muzejski trg 2, SI-6000 Koper, Slovenia. Tel.: +386 51 388 047.

http://dx.doi.org/10.1016/j.measurement.2016.02.014

that trained skiers had similar balance performance in skiing boots on or off conditions. This could imply that skiers have adapted specific balance strategies that cannot be assessed by standard balance tests. This thesis is supported by the study of Taube et al. [10] showing that the adaptations to balance training are specific to the task used in the training regime. In skiing, balance is maintained during relatively quick movements, primarily lateral body weight transfer from one leg to the other in a semi-squatting and squatting position. In addition, compression acting on the skier increases in the turns due to high radial forces and increased skiing velocity. These demands cannot be mimicked by traditional balance assessments approaches.

Another common disadvantage of standard balance tests is their low involvement of cognition, unlike during a real-life alpine skiing situation. Skiing between the gaits on the skiing course requires superior cognitive function for anticipating changes in skiing rhythm and organizing corrective or preparatory actions [11,12]. Studies focusing on effects of training on balance suggest, that superior balance is mirrored by decreased cortical and increased subcortical involvement in postural control [10]. This suggests, that balance trained athletes have more cognitive capacities available for tactical decision making, such as rhythm changes and controlling accuracy of turning. This adaptation to training might be highly important for competitive alpine skiers and should be assessed if possible.

Another set-back of common balance tests is their low demand on strength development. In skiing, short radius turns or turns during high velocity skiing expose the skier to increased compression in a semi-squat or deep-squat position due to high radial forces [13–15]. Lower centre of body mass in relation to the ground improves balance [16] but increases the demand on the strength production of the lower extremities and the trunk. Deep squat position can also cause fatigue to develop faster, having a possible negative effect on body sway control [17,18]. Consequently balance tests should be performed in a semi-squat or deep-squat position under additional load, mimicking loading during skiing.

To our knowledge no such balance specific tests exist that would incorporate aforementioned specifics of alpine skiing. The aim of this study was to assess reliability (intrasession and intersession reliability) and sensitivity of a novel dynamic lateral weight shift test. We hypothesized, that majority of the parameters used are reliable. In addition the test parameters will be able to differentiate between trained and untrained recreational skiers as well as different additional loading conditions.

2. Materials and methods

2.1. Participants

In the experiment, 12 trained (TS; [mean ± standard deviation] 21.6 ± 1.3 years; body height 183.9 ± 2.5 cm; body mass 88.5 ± 2.1 kg, competing at international level) and 22 non-trained (NS; 21.2 ± 2.1 years; body height 183.4 ± 2.8 cm; body mass 87.6 ± 1.8 kg, non-competitive recreational skiers) alpine skiers participated. Both the TS and NS participated in the sensitivity study, but only 22 NS participated in the reliability study. Participants gave their written consent to participate in the study. All procedures were in accordance with the Declaration of Helsinki and approved by the Slovenian National Committee for Medical Ethics (nr. 23p/07/12). Before enrolment the testing procedure was presented in details to each subject separately.

2.2. Study protocol and measurement procedures

Prior to testing, each subject performed a 8-min standardised warm up (a five minute run on the spot, ten deep squats and ten push-ups) followed by three 15-s familiarization trials. Prior to testing the maximal centre of pressure (CoP) excursion in medial–lateral direction was measured (participants stood in the semi-squat position and shifted their weight laterally as much as possible not lifting their opposing leg, measured for each side separately).

During each balance task the subject stood on a force plate (AMTI, Watertown, USA) in a semi-squat position (feet positioned in hip width, knees flexed at 30° and arms holding a bar placed on the shoulders), facing an online projection on the wall at a 2.5 m distance (for more information please refer to Fig. 1). The projection (size 1.5 m by 1.5 m) displayed a real time CoP position and its movement as well as a predefined trajectory composed of semi-random sinusoids. The subject could see the reference trajectory for the following five seconds and was updated ten times per second, enabling a participant to plan his/her actions in advance. For easier CoP or reference signal recognition, trajectories were of different colours and thickness. Participants goal was to pursuit the predefined trajectory with ones CoP by shifting their weight laterally (in medial–lateral direction).

The reference trajectory was composed of three different 10 s blocks. In each block three different sine signals, with randomly chosen frequency (0.1–0.4 Hz) and amplitude range (70% of the maximum CoP excursion amplitude in medial–lateral direction) were summed. After generating the reference trajectory, three different starting points were chosen, each used in a consecutive trial to enable a pseudo-random task. The same three reference trajectories were used for all participants, but their order was chosen randomly.

Each subject performed the dynamic lateral weight shifting task in three conditions: (i) no additional weight (NAW), (ii) added load equivalent to half body weight (HAW) and (iii) added load equivalent to one body weight (full additional weight, FAW). In all three conditions, participants performed three trials, each 30 s long, separated by 120 s rest intervals.

The study consisted of two experiments separated by five days. In the first experiment sensitivity of the dynamic lateral weight shift task was assessed by comparing TS and NS. In the second experiment reliability of the CoP tracking test was assessed by comparing retest data for NS. Both experiments were performed with the same measurement procedure described above.