THE LOWER EXTREMITY DEXTERITY TEST QUANTIFIES SENSORIMOTOR CONTROL FOR CROSS-COUNTRY SKIING

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Introduction:

Research on top-level cross-country skiing ability is predominately centered on the athlete´s physical fitness, biomechanical aspects of the skiing technique, and materials that make up ski hardware. Results concerning aerobic endurance capacity have been extended by new findings regarding the importance of anaerobic capacity and upper body power and strength training to improve poling form and achieve higher speeds (Sandbakk et al. 2014, Mikkola et al. 2010). Furthermore, biomechanical studies of skiing at higher speeds reveal both higher poling frequency and increased cycle length (Lindinger et al. 2009, Sandbakk et al. 2011) including the gliding phase. Finally, ski friction is measured with tribometers in specialized labs developed to improve ski-base hardware. However, despite these scientific advances, we lack a scientific understanding, and means to evaluate, the sensorimotor control mechanisms that determine gliding skill of athletes.

Gliding skill is often characterized by balance tasks (e.g. Platzer et al. 2009) but the fit to the actual skiing technique is critically under-discussed. There seems to be only a small part of skill that is transferred from a static or quasi-static task to a dynamical task like ski gliding, and as a result, differences in study results are not surprising. Hrysomallis (2011) summarized studies concerning balance ability and sport performance. Elite athletes showed better balance ability in rifle shooting, soccer and golf; however, this was not the case for alpine skiing and surfing. These findings indicate that a crucial point is the similarity of the balance task and the sport skill. In the context of dynamical balance sports like cross-country skiing, the characterizing balance task should provide the challenge of one-legged balance on unstable ground conditions.

Body position for gliding is controlled by sensory inputs including tactile information from the skin, proprioceptive information from joints, muscles and tendons, vestibular information, visual input, etc. While, a combination of these inputs directly influence motor commands of postural control, this work, however, will focus on sensorimotor control mechanisms as quantified by the Lower Extremity Dexterity (LED) test.

Hand dexterity is often defined by sensorimotor control of low-force production while manipulating objects. (Valero-Cuevas et al., 2003). Similarly,

in the case of the leg, we define dexterity as the ability to control unstable interactions with the ground (Lyle et al., 2013). The purpose of this study is to evaluate sensorimotor control of force production in the leg for gliding skills in cross-country skiers in both a one-legged balance task and the recently validated lower extremity dexterity LED test.

Methods:

Twelve young male Nordic combiners volunteered for this study. They were of national and international level with a mean age of 16.1 years (SD 1.5 ys), mean height of 176 cm (SD 6.1 cm) and a mean weight of 62 kg (SD 7.2 kg). They performed a one-legged balance test, the LED test, and a field measurement of gliding with cross-country skis on the right and the left leg separately.

Balance test:

The Biodex Balance System (Biodex, Shirley, NY) was used to measure one-legged balance ability. Subjects were asked to balance one a single leg at a time on a platform while undergoing multidirectional tilts. Because of the high performance level of the participants the difficulty level of Biodex was set at level 2. After a period of 15 seconds to adapt to the tilting properties of the platform, two trials of 20s each were performed. The amount and time of deflections from the starting position were used to calculate a stability score and the average of the two trails was defined as test score (ICC = 0.85).

Lower Extremity Dexterity (LED) test:

The lower extremity dexterity test was constructed (Lyle et al. 2013) using the model of the strength dexterity (SD) test for the hand (Valero-Cuevas et al. 2003) and was incorporated in this study. Subjects were asked to compress a slender spring prone to buckling with one foot while the body was stabilized by leaning on a bike-saddle with the upper body supported by the arms on a bar in front (see figure 1). The participant's weight is evenly distributed between the bike saddle and the support leg, allowing for isolation of the test leg. Subjects were provided visual feedback on a screen in front of them and were advised to produce a maximal compression force for at least ten seconds. Ten trials were performed and the mean of the five [[we used the best three]] best trails was calculated. This maximal level of compression (< 15% of body weight) is an indicator of the maximal instability the isolated leg can control during ground contact (ICC = 0.94).

Figure 1: athlete performing the LED test

Gliding skill:

Gliding skill was determined via

standardized gliding trials in the field. All athletes had identical ski hardware and tested in identical environmental conditions. An 80 meter section of a slope was selected and athletes were asked to glide as far as possible on one leg after two preparation steps.. The recorded measure was the distance travelled on a single ski until the second ski was lowered to stabilize body position. Ten trials were performed and the mean of the five farthest trials was determined. To ensure the reliability of the results, a second measurement was conducted one week later under comparable environmental conditions and the repeatability was shown to be acceptable (r = 0.77). Interestingly, athlete performance with respect to gliding ability, corresponded to their trainers' experience.

Body mass index (BMI) has been shown to impact balance test scores [ref?] and therefore, was incorporated into the statistical analysis to control for differing physical characteristics of the participants.

Statistics:

All measurements were performed for the right and the left leg separately and the mean values of right and left leg performance for each test were calculated. Bivariate correlations were conducted to test for interdependences in the results,. Normality of distributions of variables and residuals were checked using the Shapiro Wilk Test. A multiple linear regression of Biodex (balance), LED (leg dexterity) and BMI was used to test for predictors to gliding skill. Partial correlations contribute an insight in bivariate interdependences controlling the influence of BMI. Analyses were performed with SPSS 18 (IBM, Armonk, New York), and significance level was set at 5%.

Results:

Correlations between the LED and balance tests revealed no interdependence (r = 0.10). Gliding performance and the balance test showed a similar result (r = 0.13). A medium correlation of gliding performance and the LED test is seen (r = 0.48, ns because of the small sample size). Figure 2 shows the regression of LED test scores versus gliding performance. Partial correlation coefficients controlling for BMI between gliding and balance test scores are about zero and medium for leg dexterity (r = 0.53).

The multiple regression model predicted 47% of the variance in gliding skill (predictors: LED test, Biodex, and BMI), where only the LED test was found to be significant (p=0.03). Beta weights were 1.06, 0.59 and -0.85 for LED test, balance test, and BMI, respectively.

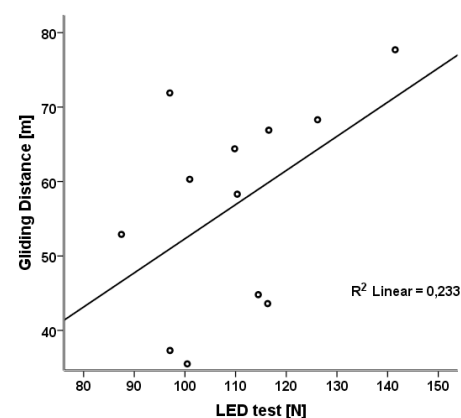Figure 2: Regression of leg dexterity (LED test) versus gliding distance

Discussion:

Our results show that the single leg balance test is not related to gliding skill. This may be because the tilting platform does not require the same dynamic stabilization as skiing. This result is more clearly illustrated when controlling for BMI. Moreover, although standing on one leg seems to correlate well with certain sports, the balance test is not able to differentiate between gliders of high and low performance. This outcome is consistent with findings of Chapman et al. (2008) who report no differences in balance ability between expert surfers and others, although the results change when considering dual tasks.

The LED test involves the simple task of controlling ground contact instabilities by compressing a spring with the foot at low force magnitudes and stresses the sensorimotor control loop focusing on the dynamic part of the force production. The dynamical nature of the LED test seems to be more similar to the gliding position and stabilization on the ski than the single leg balance task. Furthermore, as with the single leg balance test, the correlation of LED test and gliding performance is increased when BMI is controlled in the analysis. Our results suggest that the LED test is a potential tool to evaluate the sensorimotor control of the limb used for gliding during cross-country skiing.

Conclusions:

This study identified the LED test as a potential predictor of gliding skill and indicates the need for continued research into the contributing sensorimotor mechanisms of gliding. Future avenues of research will evaluate the LED test's utility as a method of evaluating new athletic training strategies and use the LED test to quantify sensorimotor processing during the in-run of ski jumping.

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