SIX WEEK CONSISTENCY OF SENSORIMOTOR TEST METHODS

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The purpose of this study was to compare sensorimotor testing methods. Therefore 15 healthy and sporty subjects undertook five different sensorimotor tests and repeated the same tests six weeks later without executing any specific sensorimotor training. The main outcome was that movement unspecific and simple tests like the Counter Movement Jump, the maximum isometric force and rate of force development on a blocked leg-press or a single-leg-stance with closed eyes have a better retest-reliability than more specific movements like a balance test on a balance board or a complex movement like a single-legged jump landing. Tests with a specific movement show a learning effect and at complex movements there was almost no correlation, as slight changes in the motion sequence can lead to big differences in the measured scores.

KEY WORDS: repeatability, control group, sensorimotor testing

INTRODUCTION: Many different testing methods for both the sensorimotor system (see Riemann et al. (Riemann and Lephart, 2002) for an overview) and postural balance (see Huxham et al. (Huxham et al., 2001)) exist. Although there is a huge choice of different testing methods; some of the methods have only been tested by the developer of the test or the manufacturer of the testing device. Some methods aim to reflect the improvement of the neuromuscular system whereas others aim to test static or dynamic balance. However, there are no gold-standards yet to test improvements in sensorimotor and balance skills caused by sensorimotor training (SMT). Recently it has been shown, that the rate of force development (RFD) can be improved by SMT (Gruber and Gollhofer, 2004). The RFD is defined as the steepness of the force-time-curve and is an important parameter to express the explosive force of the neuromuscular system. The isometric RFD of the leg extensors can be measured with a force plate fixed to a blocked leg-press. More recently it has been shown that also the maximum isometric force, which can also be measured on a blocked leg-press, can be improved by SMT (Bruhn et al., 2006). Hence, these findings indicate that the RFD method might be considered as an outcome measure for training studies of the neuromuscular system, provided it has acceptable reliability. Another method to assess improvements of the neuromuscular system is the measurement of the jump height. Therefore different jump trials can be used, like the counter movement jump (CMJ), Squat Jump or the Drop Jump at which the maximal jump height is measured. All three jump forms have been shown to be improved by SMT (Taube et al., 2007). A more functional testing method for dynamic stability that is often used to measure ankle or knee instabilities is the measurement of time-to-stabilization (TTS) or the medio-lateral displacement at a single-legged jump-landing on a stable surface (Gribble and Robinson, 2009; Ross et al., 2005; Wikstrom et al., 2005). However, jump height and test execution differ from study to study. The measurement of the displacement of the Centre of Pressure (CoP) in a single-leg-stance without previous performance of dynamic postural tasks is applied to quantify the postural sway in static standing position. The MFT S3-Check is a testing device for dynamic standing stability on an unstable support surface, which shows good reliability, objectivity and validity according to a study of the manufacturer (Raschner et al., 2008). The MFT-Board is a board that can be tilted up to 12° to the left or the right side or from forward to backward, depending on the standing position on the board.

The aim of this study was to determine which of these sensorimotor tests have an acceptable reliability and could therefore be chosen with confidence to test the progress of a SMT intervention.

METHOD: 15 healthy recreationally active subjects aged between 18 and 25 years (5m / 10f) have twice undertaken the following sensorimotor tests with 6 weeks between the tests. During these 6 weeks, the subjects were not allowed to undergo any SMT. The subjects were allowed to continue their normal training program, however, were requested to fill in a training log.

Single-leg stance: The displacement of the CoP was measured by a force plate (Kistler, Winterthur, Switzerland) with a sampling frequency of 2000 Hz for 5 seconds per trial. The subjects had to stand on their dominant foot (the one they use to shoot when playing soccer) with arms akimbo and closed eyes. The mean values of the better two trials were measured for the path length and the moving area. The path length was calculated by summing up the distances between consecutive data points. The moving area was calculated as the summed up areas of the triangles between the geometric center of all the points and two consecutive data points.

Single-leg jump landing: At a single-leg jump landing from 36cm height the vertical, medio-lateral and anterior-posterior ground reaction forces were measured with a force plate (Kistler, Winterthur, Switzerland). The TTS scores were calculated with the sequential estimation method using an algorithm to calculate a cumulative average of the data points in a series by successively adding one point at a time (For more details see Ross et al. (Ross et al., 2005), Gribble et al. (Gribble and Robinson, 2009) or Wikstrom et al. (Wikstrom et al., 2005)). In addition, the medio-lateral displacement of the knee has been measured by filming the frontal plane movement of a cross that has been marked on the knee of the subjects. These videos have then been evaluated using a video tracking software (Skill Spector, video4coach, Svendborg, Denmark) to determine the maximal medio-lateral displacement of the knee. For all the single-leg jump measurements the mean of the best two out of three jumps has been taken for statistical analysis.

MFT S3-Check: For the MFT S3-Check the subjects tried to stay as calm as possible on a MFT platform for 30 seconds with their arms akimbo. The mean values of the better two of the three trials were taken for statistical analysis. The stability-index values are automatically calculated, whereas a low number stands for good balance.

Counter Movement Jump: Five CMJ with arms akimbo were performed by the subjects on a QuattroJump-platform (Kistler, Winterthur, Switzerland). The mean of the best two jump heights and the corresponding maximal RFD over 50ms were measured.

Leg-press: On a blocked 45°-leg-press with a fixed force plate on the foot-part, the subjects had to push as explosively and hard as they could. Their knee-angle has been set to 90° and the test has been repeated 5 times. The maximum isometric force and the maximal RFD over 50ms have been measured.

With Matlab R2009b the mathematical process has been executed and then the statistical analysis has been performed with SPSS Statistics 17.0. A dependent t-test for paired samples was applied to calculate, whether significant differences had occurred between the tests. With interclass-correlation the ICC-value has been calculated.

RESULTS: There are significant ($p<0.05$) differences between the pre- and post-test for the anterior-posterior TTS score and the medio-lateral knee displacement at single-leg landing (Tab. 1). Additionally there are trends towards significance for the vertical TTS score and the stability-index of the MFT S3-Check. All of these tests except for the stability-index, which shows moderate correlation, also show low correlation values. In addition also the medio-lateral TTS at single-leg landing and the RFD at CMJ show low correlation values. Both path length as well as motion area that were assessed at single-leg stance, show moderate to good correlation values. Good correlation values were achieved for the CMJ jump height, as well as for the measurements that were applied at the blocked leg-press, the maximal force as well as the RFD value. All subjects had filled out their diaries and abided to the demands not to undergo any SMT during the intervention.

Table 1. Mean values, number of subjects (N), standard deviation (SD), correlation (ICC) and level of significance (*p*) of the different sensorimotor tests, * significant (*p*<0.05).

	Mean	N	SD	ICC	*p*
Single-Leg-Stance_Path_pre [mm]	382.4	15	74.2	.775	.660
Single-Leg-Stance_Path_post [mm]	376.2	15	83.0		
Single-Leg-Stance_Area_pre [mm^2]	3906	15	1130	.859	.860
Single-Leg-Stance_Area_post [mm^2]	3936	15	1304		
Landing_Knee-Motion_pre [cm]	6.6	15	3.2	.208	.010*
Landing_Knee-Motion_post [cm]	4.4	15	0.9		
Landing_TTS_medio-lateral_pre [s]	1.44	15	0.08	.537	.111
Landing_TTS_medio-lateral_post [s]	1.41	15	0.06		
Landing_TTS_anterior-posterior_pre [s]	1.38	15	0.04	.441	.025*
Landing_TTS_anterior-posterior_post [s]	1.35	15	0.03		
Landing_TTS_vertical_pre [s]	1.32	15	0.07	.564	.091
Landing_TTS_vertical_post [s]	1.30	15	0.06		
CMJ_height_pre [cm]	41.1	15	7.4	.952	.837
CMJ_height_post [cm]	40.9	15	7.6		
CMJ_RFD50_pre [N]	451	15	159	.461	.711
CMJ_RFD50_post [N]	466	15	141		
Leg-Press_RFD50 _pre [N]	700	15	392	.824	.157
Leg-Press_RFD50 _post [N]	611	15	370		
Leg-Press_maxF _pre [N]	2100	15	735	.970	.332
Leg-Press_maxF _post [N]	2011	15	627		
MFT_Stability_pre	5.11	15	0.61	.695	.077
MFT_Stability_post	4.90	15	0.45		

DISCUSSION: Because of the good outcome values and the simple implementation, the single-leg stance is thought to be a robust method to test the static balance. A suboptimal choice to quantify improvements in balance or sensorimotor skills is the single-leg jump landing as correlation scores are very low, probably caused by the complexity of the movement in which slight changes in the motion sequence can lead to big differences in the measured scores. This outcome correlates with the findings of Ross et al. (Ross et al., 2005) who showed low to moderate reliabilities at TTS-scores in single-leg jump landings. The significant change in the values anterior-posterior TTS score and the medio-lateral knee displacement at single-leg landing could be explained by a learning effect due to the first test session. The jump height at CMJ seems to be a very useful and easily applicable dynamic method as long as no strength training is performed during the same intervention period as this can lead to falsification of the results. The dynamic RFD, however, is a very poor indicator as a slightly changed knee angle leads to a totally different RFD. This is also reflected in the low correlation value. Good correlation values were also found at the blocked leg press for the maximal force as well as the RFD. However, the same problem as with the jump height of the CMJ occurs: any strength training performed during an intervention period can lead to falsification of the results. As near-significant improvements have been found, the stability-index of the MFT S3-Check needs further investigation whether it is appropriate as a testing device for scientific studies or not. The movement is very task-specific and can probably be learned by training on a tilt-board. Based on the present study it is not possible to decide if a test is suitable to detect a change due to SMT, however it provides valuable data on the test reliability and therefore sets a baseline to judge whether differences from post to pre intervention may be accounted to the SMT or are in the range of interest variability.

CONCLUSION: Tests with a simple movement like the CMJ, the isometric RFD and the maximal force at the locked leg-press or the path length and motion area at single-leg stance show the highest reliability values. Specific movements (like S3) show a learning effect and at complex movements like the single-leg landing task there was almost no correlation, possibly because slight changes in the motion sequence lead to big differences in the measured scores. Therefore, such specific tests should not be applied to quantify general improvements of sensorimotor skills.

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