ASSESSMENT OF SENSORIMOTOR FUNCTIONS: FROM THE LAB TO THE FIELD

POSUDZOVANIE SENZOMOTORICKÝCH FUNKCIÍ: Z LABORATÓRIA NA ŠPORTOVISKO

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Abstract

This study deals with our findings related to the assessment of sensorimotor functions under the laboratory and field testing conditions. This includes the agility test for measurement of agility or sensorimotor time, reaction tests for measurement of simple and multi-choice reaction time, visually-triggered step initiation test for measurement of movement time or speed of step initiation, and tapping tests for measurement of frequency of movements of upper and lower limbs. These tests were found to be reliable and sensitive to differences among various populations. They may be used for evaluating the physical fitness of individuals and also the efficiency of exercise or rehabilitation programs. Together with tests of body balance, core stability, muscle strength and power, these tests can be included into current testing batteries and so complement existing methods.

Key words: agility test, foot and hand tapping, simple and choice reaction tests, step initiation test

Introduction

Given the importance of neuromuscular and sensorimotor functions in activities of daily living, their assessment should be considered an integral part of functional diagnostics (Zemková, 2015). The previous study provided an overview of tests for the assessment of balance under a variety of conditions. These include static balance tests, a test of dynamic balance, task-oriented balance tests and a load release balance test (see a review by Zemková et al., 2016). Following study focused on tests evaluating the core stability and strength. As an example were introduced instrumented torsional tests, a load release balance test complemented with measurement of trunk motion, tests of maximal isometric strength of back muscles and muscle power during a lifting task (see a review by Zemková et al., 2017). The present study continues with the presentation of tests for the assessment of sensorimotor functions under the laboratory and field testing conditions.

Measurement of sensorimotor or agility time

In one of our former studies, the effect of 3 months of proprioceptive stimulation training on parameters of agility, balance and strength in older women was evaluated (Zemková et al., 2004; Zemková et al., 2006). A total of 32 women were randomly divided into two experimental groups, and underwent two forms of exercise under the influence of proprioceptive stimulation, during a training conducted 3 times a week. While the experimental group 1 (EG1) performed semi-squats (6 sets of 10 repetitions without and with an additional load of 20% of body weight, separated by 2 minutes of a rest), the experimental group 2 (EG2) stood in a semi-squat position on a vibration platform (6 sets of 30 and 45 seconds, separated by 2 minutes of rest). Proprioceptive stimuli were applied by means of a platform producing short-term counter shocks (ground reaction force increases of about 1 G within 3 ms at the frequency of 10 Hz). Parameters of agility were evaluated prior to and after the training using the FiTRO Agility Check (FiTRONiC, SVK). Results showed a significant improvement of agility time in EG1 and EG2. This effect was slightly higher in subjects performing semi-squats (13.6%) than was evident in those standing in semi-squat position on a platform (11.6%). On the other hand, the control group failed to show any significant reduction in agility time. Such positive changes may be ascribed to the improvement of neuroregulatory functions, namely an increased rate of motoneuron firing and better synchronisation of motor unit activation. It was concluded that serial mechanical proprioceptive stimulation applied to the lower extremities enhances agility performance in older women.

The agility test used in this study, consists of stimulus perception, decision-making and execution of movement. Its advantage is that it evaluates both the sensory and the motor aspects of agility performance. As a result, the test provides information regarding sensorimotor or agility time that includes the choice reaction time and movement time. The subject is instructed to use either the left or right lower limb to make contact with one of the four mats located in four corners outside of a pre-defined (e.g., 40 cm) square (Figure 1). They are encouraged to perform this test as quickly as possible and to touch the mats in accordance with the location of the stimulus in one of the corners of the screen. In addition to the reactions from a position in the middle of the square of four mats, they can also respond from the location of the last stimulus. The results are recorded as the total agility time (AT) and AT in each direction of movement (Figure 2).

The test can be adjusted according to the individual needs. The diagnostic system offers a variety of test settings, such as time generation (constant or random), number of stimuli, forms and colors of stimuli, as well as background color. It can be also performed under varied conditions differing in a) number of contact mats (2 and 4), b) distance between mats and the subject (0.4 m, 0.8 m, 1.6 m, and 3.2 m), c) their alignment (square and semi-arch), d) positioning (underfoot and aloft of thorax), and e) size (6.5 x 6.5 cm and 35 x 35 cm). More information about the assessment of agility performance can be found in a book by Zemková and Hamar (2015).

Figure 1 Measurement of agility time using the FiTRO Agility Check

Test: Protocol Yellow Circle on Black
Name:
Date: 27.04.2007 at 09:39:39

Protocol Name: protocol2

MOVEMENT DIRECTION	N (#)	BEST (ms)	WORST (ms)	AVERAGE (ms)	SD (ms)
rear left	15	511	1236	654,3	175,5
rear right	15	497	1197	665,8	206,0
front left	15	486	1336	586,9	203,7
front right	15	432	1267	609,8	188,3
** TOTAL **	60	432	1336	629,2	196,4

Figure 2 Summary report of the agility test

Thus, agility testing addresses both the cognitive and the physical component. Both of them contribute to the agility performance, although to a different extent (Zemková, Hamar, 2017). The Agility Index, defined as a ratio of reaction time and agility time which is divided by the previously determined coefficient for each distance traveled, allows to estimate the contribution of movement time to the agility performance (Zemková, 2016). Therefore, the agility test should be complemented with measurements of multi-choice reaction time and movement time or velocity.

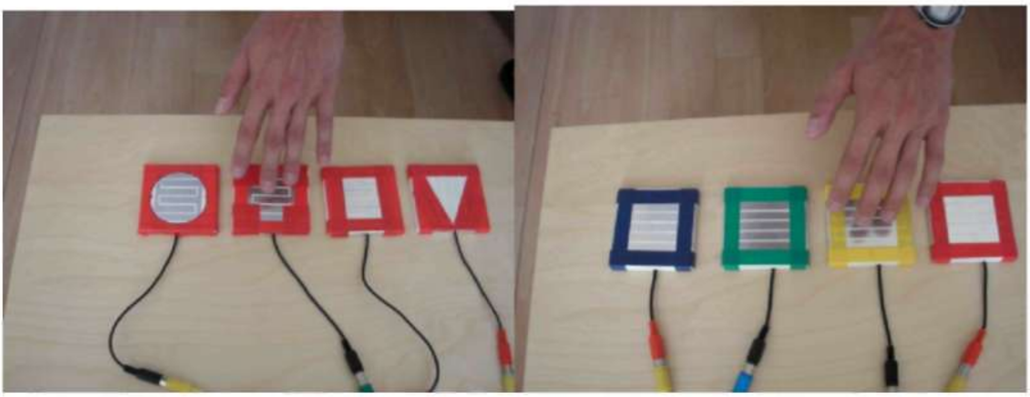
Measurement of simple and multi-choice reaction time

Simple reaction time is the interval between the appearance of the stimulus and the beginning of response. Multi-choice reaction time includes stimulus identification as well as response selection to various stimuli. In this case, reaction time is an indicator of the speed and effectiveness of decision-making.

Reaction time figures prominently in the open skills required in many sports and ordinary daily activities such as catching a glass falling from a cupboard. For instance, half a second (reaction time to two stimuli) could be the time it takes for a driver to brake when someone unexpectedly enters the street. During that time, the car moves 6.9 m at a speed of 50 $km.h^{-1}$, 11.1 m at 80 $km.h^{-1}$, and 13.8 m at 100 $km.h^{-1}$. It seems obvious that a fast and accurate response to a stimulus can significantly influence an outcome. Therefore, obtaining information on reaction times in daily situations can be of great value. In general, the average threshold is shorter for kinesthetic (120 – 140 ms) and auditory reaction time (140 – 160 ms) than for response to visual stimuli (180 – 220 ms) (Vickers, 2007). However, variables such as forms, color, intensity, number of stimuli and their compatibility (e.g., laterally concordant and discordant stimuli) play a role in speed of responses.

In the reaction test, the subject may respond to either one (simple reaction time) or more stimuli of different forms or colors (multi-choice reaction time) randomly generated by the diagnostic system FiTRO Reaction Check (FiTRONiC, SVK) (Figure 3 a–d). The result is a total reaction time (RT) and the RT from a defined number of reactions. Correct and false responses are both recorded (Figure 4).

a b



c d

Figure 3 (a) Diagnostic system FiTRO Reaction Check for measurement of (b) simple and (c, d) multi-choice reaction time to stimuli of different forms and colors

Name:
Total: 20
square: Red circle: Red

Date: 25.10.2007 at 19:16:02
Background: White
triangle: Red cross: Red

No (#)	Object	Generation Time (ms)	Reaction Time (ms)	Total Time (ms)	Quality
1	Triangel	800	1984	2784	correct
2	Cross	800	1746	2546	correct
3	Circle	800	2004	2804	correct
4	Circle	800	1908	2708	correct
5	Triangel	800	1724	2524	correct
6	Cross	800	1536	2336	correct
7	Square	800	1735	2535	correct
8	Square	800	2375	3175	correct
9	Triangel	800	1904	2704	correct
10	Cross	800	1558	2358	correct
11	Cross	800	1592	2392	correct
12	Circle	800	1729	2529	correct
13	Square	800	1759	2559	correct
14	Triangel	800	1581	2381	correct
15	Circle	800	2331	3131	correct
16	Square	800	1777	2577	correct
17	Circle	800	2542	3342	correct
18	Square	800	1690	2490	correct
19	Triangel	800	1727	2527	correct
20	Cross	800	1636	2436	correct

Figure 4 Summary report of the reaction test

We have investigated the reaction time and sway velocity while responding to visual stimuli concurrently with balancing on a wobble board (Zemková et al., 2009b). Findings showed that reaction time increases while balancing on an unstable support surface, whereas sway velocity declines when concurrently performing reaction tasks. Following study extended this research by evaluating the effect of 8 weeks of instability agility training on choice reaction time and balance under various conditions (Zemková et al., 2009a). Balance exercises performed simultaneously with reaction tasks were found to be an effective mean for the improvement of dynamic balance, namely when responding to visual stimuli, as well as for reduction of multi-choice reaction time. These findings indicate that attempting two tasks at the same time, both of which require controlled processing, can have a varied impact on a person´s performance depending on the task specificity.

Measurement of movement time

Measurement of the speed of step initiation is often used in rehabilitation and clinical practice. However, most of these tests are based on pre-planned steps with no perceptual component, such as reaction to a given stimulus. In a novel visually-triggered step initiation test subjects perform 3 trials of simple stepping reactions responding to a visual stimulus (Figure 5 a, b). The test is initiated with the subject standing on two mats placed in front of the light signal. When the light switch on, the subject perform two steps (starting with dominant leg) moving to mats (with 30 cm sides) marked with tape on a floor with a 60 – 70 cm distance apart. Subjects are instructed to perform the steps as quickly as possible. The time of foot off (onset of unloading) and foot contact time (from foot-off to foot-contact) of the first step are recorded by means of the FiTRO K-Reaction Check (FiTRONiC, SVK). The best score of 3 trials is recorded for analysis.

Including a perceptual component into the step initiation test would reflect real-life situations more effectively. However, problematic reproducibility and lack of precision outside of acceptable limits when compared to accurate laboratory tests, limits the visually-triggered step initiation test as a viable alternative to currently used methods, namely for quantifying slight changes in performance of individuals and small groups (Zemková et al., 2010b).

a b

Figure 5 (a) Measurement of reaction and movement times during step initiation by means of the FiTRO K-Reaction Check, and (b) speed of step initiation using the FiTRO Dyne Premium

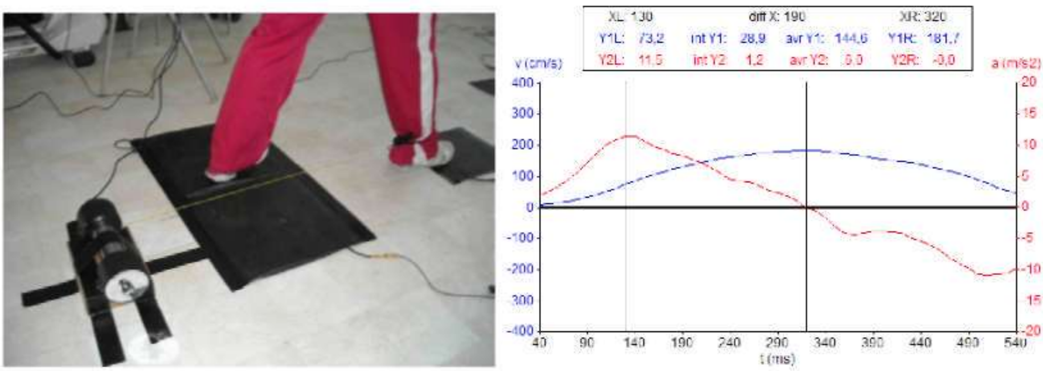
In order to increase the task difficulty during reactive step execution, a randomly alternating sit-to-stand-to-step and stand-to-sit-to-stand-to-step could be introduced. We suggested that these conditions might better differentiate simple foot reactions among healthy young individuals. Implementing more demanding conditions in the testing protocols is based on the fact that step execution is not always performed from standing position, but also after rising from a chair. Another motive was to include decision-making process in responses to two stimuli. Such a test would be closer to actual real life situations. It would involve cognitive processing (perception and decision making), motor component (strength and movement speed), in addition to technical skills (footwork and movement technique).

We investigated whether increasing the difficulty of the task during reactive step execution would better differentiate the simple foot reactions in healthy young people (Zemková et al., 2010a). While the step execution in the first test began from a standing position, rising from a chair was included into the second and third test (sit-to-stand-to-step and stand-to-sit-to-stand-to-step, respectively) (Figure 6 a–c). Findings indicate that increasing the difficulty of the task during reactive step execution is more effective in differentiating simple foot reactions among healthy young individuals. Despite the fact that the visually-triggered step initiation test exhibits the potential to discriminate between individuals, in addition to the ability to distinguish between different testing conditions, it also displays a low reliability in the time of foot off and foot contact time which means it has limited application value in practice.

a b c

Figure 6 (a–c) Task execution: sit-to-stand-to-step

An appropriate alternative would be to measure the speed of step initiation by means of the system FiTRO Dyne Premium (FiTRONiC, SVK) based on precise analogue velocity sensor with sampling rate of 100 Hz. Since a previous study has identified a significant relationship between the foot flight time (from foot-off to foot-contact) measured by means of the FiTRO K-Reaction Check and maximal step velocity measured by means of the FiTRO Dyne Premium (r = 0.84) (Zemková et al., 2010a), such measurements may be a viable alternative to the previous test. Subjects are instructed to perform 3 trials of voluntary steps, i.e. using their own initiative. The device is mounted to the wall and a nylon tether is attached to the ankle of the subject. His/her task is to perform the step while pulling on the nylon tether of the device (Figure 7 a). The best score of the 3 trials is used for analysis. Maximal and mean velocities in the acceleration phase of the stepping process, in addition to the maximal and mean acceleration, can be recorded for analysis (Figure 7 b). However, the maximal velocity of the step initiation as the most reliable parameter should be used in practice (Zemková et al., 2013a). The test is also sufficiently sensitive in discriminating between individuals of various ages and fitness levels. Interestingly, sedentary young and physically active older subjects all performed the steps in a similar time, indicating that physical fitness rather than age plays a role in the speed of step initiation.



a b

Figure 7 (a) Measurement of speed of step initiation using the FiTRO Dyne Premium and (b) and an example of the parameters being analyzed

A more sophisticated alternative represents the system FiTRO Step Initiation Check (FiTRONiC, SVK) consisting of large force platform covered by a contact mat (Figure 8 a, b). Besides parameters of step initiation, also the trajectory of the center of pressure in X– and Y-axis is registered. Subjects can perform a variety of steps, e.g., visually-triggered step initiation, voluntary step, i.e. using their own initiative, step with eyes closed, or back step.

a b

Figure 8 (a, b) Measurement of reaction time and movement time and/or speed of step initiation using the FiTRO Step Initiation Check

Our recent study evaluated the effect of 3 months of resistance and aerobic training programs on step initiation speed and foot tapping frequency in the overweight and obese (Zemková et al., 2017). Subsequent to both aerobic and resistance training, there was a significant decrease in the time from foot-off to foot-contact during spontaneous step initiation, visually triggered step initiation, and step initiation with eyes closed. However, mean CoP trajectory in X-axis during the back step, spontaneous step initiation, visually triggered step initiation, and step initiation with eyes closed decreased significantly following the resistance training only. On the other hand, the number and frequency of taps increased significantly following the aerobic training, concurrently with a significant decrease in flight time. It was concluded that both aerobic and resistance training, for a period of 3 months, increase the speed of step initiation in overweight and obese individuals. However, medio-lateral postural stability during step execution improves after the resistance training but fails to improve following the aerobic training. In contrast, foot tapping frequency increases after the aerobic training but not after the resistance training.

Measurement of movement frequency

The assessment of speed abilities can be conducted by measuring the movement frequency of the upper (Figure 9) and lower limbs (Figure 10 a, b), usually in duration of 10 seconds. The tapping of lower limbs can be performed in standing or sitting positions when required, for example by older adults, the overweight and obese or in those with impaired neuromuscular functions, e.g., Parkinson patients. In such cases, a shorter contact time and longer flight time can be expected. Basic parameters such as the number and frequency of the movement of lower limbs (f), contact time (Tc), and flight time (Tf) of each leg or average of both legs are measured by means of the FiTRO Tapping Check (FiTRONiC, SVK) (Figure 11).

Figure 9 Measurement of frequency of movement of upper limbs using the FiTRO Tapping Check

a b

Figure 10 Measurement of frequency of movement of lower limbs in (a) standing and (b) sitting position using the FiTRO Tapping Check

PERIOD		No #	Right Tc (ms)	Foot Tf (ms)	f (Hz)	No #	Left Tc (ms)	Foot Tf (ms)	f (Hz)	No #	R-L Tc (ms)	MEAN Tf (ms)	f (Hz)
AV	0 - 10	47	80	135	4,63	45	69	143	4,69	92	74	139	9,32
SD	0 - 10	47	10	9	0,22	45	16	12	0,34	92	14	11	4,65

Figure 11 Summary report of the tapping test

We have found that the number and frequency of lower limb movements escalate with increasing age, the maximum is recorded by adults, which then begin to decline with increasing age ranges (Zemková et al., 2013b). Contact and flight times display a similar tendency, with the lowest values in subjects ranging from 19 to 24 years of age. Interestingly, while there are no significant differences in flight time between groups ranging in age from 19 to 24 years or from 55 to 64 years, contact time significantly decreases in younger as compared to older adults. In addition, there are no significant differences either in number or frequency of lower limb movements, or in contact and flight times between legs. These findings indicate that the test is able to discriminate the tapping frequency of the lower limbs in groups of subjects of various ages.

Conclusion

This study presents our approach to testing of sensorimotor functions. Besides a variety of balance tests, this also involves the agility test, simple and choice reaction tests, a visually-triggered step initiation test, and foot and hand tapping tests. Using portable diagnostic systems, most of these tests can be performed in clinics, rehabilitation and fitness centres. They may be useful for evaluating levels of physical performance in various populations, as well as assessing the efficiency of the exercise or rehabilitation program.

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