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METHODOLOGICAL APPROACH TO ASSESSING POSTURAL AND CORE STABILITY

METODOLOGICKÝ PRÍSTUP K POSUDZOVANIU STABILITY POSTOJA A TRUPU

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Abstract

This study presents a methodological approach to assessing postural and core stability in people of different ages and level of physical fitness. It includes tests of (i) postural and core stability under stable and unstable conditions, (ii) postural stability after an unexpected perturbation, (iii) postural control during a task-oriented balance test, and (iv) maximal isometric back extensor muscle strength. This test battery can be complement with other field tests of body

balance and core strength. It can be applied in an evaluation of actual performance in general population as well as its changes after exercise programs.

Key words: center of mass, center of pressure, static balance, dynamic balance, core muscle strength

Introduction

Previous studies have provided an overview of body balance tests (Zemková et al., 2016b) and core stability and strength tests (Zemková et al., 2017a) and their applications in various populations (Valkovič et al., 2012; Zemková et al., 2016d; Janura et al., 2017; Lehnert et al., 2017; Zemková, 2017a; Zemková et al., 2017b; Zemková, 2018; Ebenbichler et al., 2019; Zemková et al., 2020) and after short- and long-term training or rehabilitation programs (Oddsson et al., 2007; Zemková et al., 2007; Zemková, Vlašič, 2009; Zemková et al., 2017c; Zemková et al., 2017d; Zemková, Hamar, 2018). In the current study, mainly tests used for evaluation of physically active and sedentary individuals who are prone to back pain will be presented. This includes static and dynamic balance tests, a task-oriented balance test, a perturbation-based balance test, and the test of maximal isometric strength and endurance of back muscles (detailed described in a book by Zemková, 2019).

Assessment of postural stability under stable and unstable conditions

Data related to the static and dynamic balance can be obtained by using the Biodex® Balance System (Biodex Medical Systems Inc., Shirley, New York). This system consists of a circular platform that is free to move in the anterior-posterior and medial-lateral axes simultaneously, and is able to control the movement degree of the platform with 12 levels (Figure 1). Eight springs located underneath the outer edge of the platform provide the resistance to movements and induce different levels of instability. The degree of surface instability is controlled by the system's microprocessor-based actuator. This device is interfaced with a software that allows to measure the degree of tilt in each axis, providing an average sway score. It samples sway deviations in anterior–posterior and medial–lateral directions and calculates the anterior–posterior index, medial–lateral index and overall stability index (Figure 2).

Postural stability assessment using Biodex stability system demonstrates good-to-excellent test-retest reliability (Arifin et al., 2014). The ICCs for the overall stability index, anterior-posterior stability index and medial-lateral stability index are 0.85, 0.78 and 0.84 during static condition and 0.77, 0.77 and 0.65 during dynamic condition, respectively (Arifin et al., 2014). Biodex Balance System stability indices are also reliable measures of postural control in the chronic low back pain patients, especially in more challenging conditions when standing with eyes closed (Sherafat et al., 2013). The intersession ICCs in chronic low back pain group for anterior-posterior stability index ranges from 0.60 to 0.88, for medial-lateral stability index ranges from 0.64 to 0.94, and for overall stability index ranges from 0.63 to 0.91 (Sherafat et al., 2013). The intersession ICCs in healthy group for anterior-posterior stability index ranges from 0.42 to 0.86, for medial-lateral stability index ranges from 0.56 to 0.89, and for overall stability index ranges from 0.54 to 0.84 (Sherafat et al., 2013).

Figure 1 Static and dynamic balance tests

Figure 2 An example of test result

Assessment of postural and core stability under stable conditions

Static posturography is used to analyse a time-course of center of pressure (CoP). Basic testing protocol requires subjects to stand barefoot on a force plate with their arms relaxed comfortably at their sides (Figure 3). They are instructed to stand in an upright posture with their feet abducted 10° and their heels separated mediolaterally by a distance of 6 cm. A series of two trials are conducted in random order under different conditions with less or more demanding postural tasks. These include different surfaces (firm, foam) (Figure 4 a, b), stances (bipedal, unipedal), feet position (semi-tandem, tandem) (Figure 5), knee and hip angles (weight-bearing-leg: knee fully extended, knee flexed 10-20°; non-weight-bearing leg: knee flexed 90°, hip flexed 0° or 45°), arms position (at the side, crossed over the chest, fixed on the hips), visual inputs (eyes open, eyes fixed on a stationary target, eyes closed), and so forth. Each test consists of two 30-second trials and the better result is taken for the evaluation, unless it is specified otherwise (e.g., while testing balance in people with impaired postural control).

Basic parameters of postural sway (mean CoP position in the X- and Y-axis, mean CoP velocity, mean CoP acceleration, mean trace length of the CoP, mean distance from the middle of the CoP, mean squared distance from the middle of the CoP, and trace area of the CoP) are registered by using a FiTRO Sway Check system (FiTRONiC, Slovakia). The force plate data is sampled at a frequency of 100 Hz. Analyses of repeated measurements identified that the most reliable parameter is mean CoP velocity with the test-retest correlation coefficient of 0.819 and the measurement error of 10.4% (Zemková, Hamar, 2002). The mean of two 30-second trials recorded for evaluation is considered as a reliable measure of postural stability ($r = 0.987$). In a case of shorter test duration, five 10-second trials are required to obtain reliable results ($r = 0.946$). There are no significant day-to-day changes in measures of postural stability which signify stability of measurement.

Figure 3 Static balance test

Figure 4 Standing on a force plate (a) and a foam surface placed on the force plate (b)

Figure 5 Bipedal (a), unipedal (b), semi-tandem (c), and tandem (d) stance

Assessment of postural and core stability under unstable conditions

Usually, dynamic posturography is used for assessment of postural stability under unstable conditions. External perturbations can be induced from a platform either shifting in antero-posterior (A-P) and medio-lateral (M-L) direction or tilting the toes up and down. Various protocols, based on varied determinants of plate translation, such as the direction (forward, backward, left-lateral, and right-lateral), displacement (from 1 cm to 14 cm), and velocity (5 $cm.s^{-1}$, 10 $cm.s^{-1}$, 15 $cm.s^{-1}$, and 20 $cm.s^{-1}$), can be designed (Zemková et al., 2016c). Concurrently with measurement of dynamic balance, trunk movement representing roughly the center of mass (CoM) movement can also be monitored using the FiTRO Dyne Premium (FiTRONiC, Slovakia). Although most of dynamic posturography systems have been employed for clinical examination of patients with balance disorders, these mostly laboratory tests cannot fulfill the needs for assessment of balance under field conditions. The practice implies that computerized portable devices that are more applicable to routine testing in field conditions are preferred over laboratory techniques.

Alternatively, a stance on a spring-supported platform can be used for assessing the postural stability under dynamic conditions (Figure 6). The device consists of a triangular plate supported by 3 springs with a coefficient of elasticity of 30 $N.mm^{-1}$. Shifting the center of mass in the horizontal plane leads to changes of body weight distribution to the 3 corners of the platform. The force acting in each corner is calculated as a product of the coefficient of elasticity of the spring used and the vertical distance measured by means of a fine sensor. The analog signals are AD-converted and sampled by computer at the rate of 100 Hz. Calculations of an instant CoP position is based on force distribution to the 3 corners of the platform. From instant values of CoP position, a stabilographic curve is constructed (Figure 8a). From such a curve, variables of postural sway are calculated and registered by using the FiTRO Sway Check system (FiTRONiC, Slovakia).

Experience indicates that standing on an unstable foam surface or a spring-supported platform while testing body balance is more efficient in discriminating within-group and between-group differences when compared to static balance tests (Zemková et al., 2015). A recent study showed that unstable conditions improve the discriminatory accuracy of balance tests with both eyes open and eyes closed (Zemková et al., 2018). Comparing static balance tests with eyes open and eyes closed (AUC = 0.66, 95% CI = 0.62–0.69 and 0.70, 95% CI = 0.65–0.74, respectively), testing of postural stability while standing on a spring-supported platform significantly increases the discriminatory power (AUC = 0.82, 95% CI = 0.78–0.86; p = 0.006 and 0.87, 95% CI = 0.84–0.90; p = 0.009, respectively) in healthy young, early and late middle-aged adults. Assessment of balance under unstable conditions, coupled with or without visual references, is also able to reveal slight changes in the postural control throughout the lifespan as well as after exercise programs focused on improvement of sensorimotor functions (Zemková, 2009; Zemková, 2010). However, frequently used statistical significance in balance research does not imply that changes observed after the training are practically meaningful, or vice versa. Therefore, both *P* values and effect sizes should be used when interpreting results of cross-sectional and intervention balance studies (Zemková, 2014).

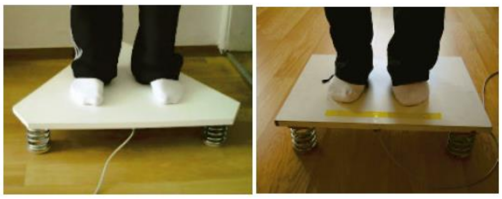

Figure 6 Standing on a spring-supported platform

Simultaneously, center of mass (CoM) movements can be measured (Figure 7) using the Gyko inertial sensor system (Microgate, Bolzano, Italy) placed on the trunk. The Gyko system consists of 3D accelerometer for measurement of linear accelerations to which the device is subjected, 3D gyroscope for measurement of angular velocities of the device, and 3D magnetometer for measurement of a magnetic field to which the device is subjected. It provides data measurements up to 1000 times per second (1 kHz) which guarantee their high temporal resolution. On the basis of these data, specific software algorithms describe the kinematics of the analysed body segment. It determines three main measures of body sway: sway length and area, sway travel speed, and sway frequency (Figure 8b). Recent study by Jaworski et al. (2020) reported moderate to good relative reliability scores for all the postural stability measures, with

ICC values ranging from 0.62 to 0.70. For most of the analysed variables, SEM% ranged from ~10% to 14%.

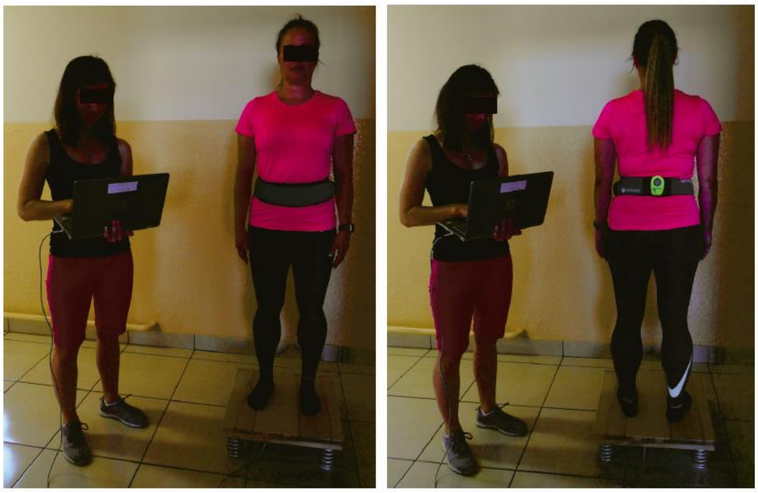

Figure 7 Dynamic balance test

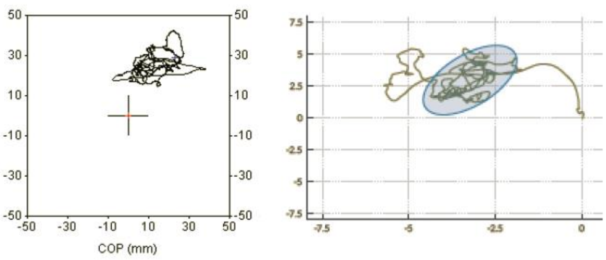

Figure 8 An example of CoP (a) and CoM (b) movements during the test

Assessment of postural and core stability after an unexpected perturbation

Another alternative represents external perturbations applied directly to the body by pushing/pulling the trunk, the shoulders or pelvis. This also includes trunk repositioning and load release tasks (Reeves et al., 2007; Silfies et al., 2007; Jørgensen et al., 2011) which are a quick-to-administer and can be performed in field conditions. The trunk repositioning tasks require a subject to actively or passively return to a neutral spine position following a predefined displacement. Load release tasks require the subject to perform an isometric trunk contraction at a predefined intensity against an external load, which is subsequently released, and the displacement of the trunk is quantified. The voluntary surface electromyography can be recorded from the core musculature to examine the on–off activation of muscles following release.

Subjects stand barefoot on a force plate with their arms held horizontally forward, a shoulder width apart (Figure 9a). They are required to hold a bar in their hands with a 2 kg load fixed to the bar. A signal from the computer triggers a random release of the load over a 5-s period following the initiation of the test, thus the subject receives no cues as to when the perturbation would occur. The release of the load produces a sudden change in the external forces acting on the subject, leading to a small anterior and then a larger posterior displacement of the subject's CoP. The perturbation after the load fall causes only a postural sway response, i.e. the subject does not need to take a step to maintain balance. The perturbation is quantified by the maximal anterior and posterior displacement, within one second after the load drop. The recording ends 2-3 seconds after the load-drop.

A series of three trials are conducted in random order under varied conditions while the best result is selected for evaluation. Peak anterior displacement of the subject's CoP, the time to peak anterior displacement of the subject's CoP, peak posterior displacement of the subject's CoP, the time to peak posterior displacement of the subject's CoP, total anterior to posterior displacement of the subject's CoP, and the time from peak anterior to peak posterior displacement of the subject's CoP, are registered by using the FiTRO Sway Check system, completed with a special program for Load Release Balance Test (FiTRONiC, Slovakia) (Figure 10). The force plate data is sampled at a frequency of 100 Hz. Previous study identified that test-retest reliability of parameters of the load release balance test is good to excellent, with high values of ICC (0.78-0.92) and low SEM (7.1%-10.7%) (Zemková et al., 2016e). The area under the ROC curve >0.80 for these variables indicates good discriminatory accuracy in differentiating between groups of physically active and sedentary adults as early as from 19 years of age. Concurrently with measurement of postural stability in terms of CoP movement, trunk stability representing roughly the CoM movement can also be monitored using the FiTRO Dyne Premium (FiTRONiC, Slovakia) (Figure 9b).

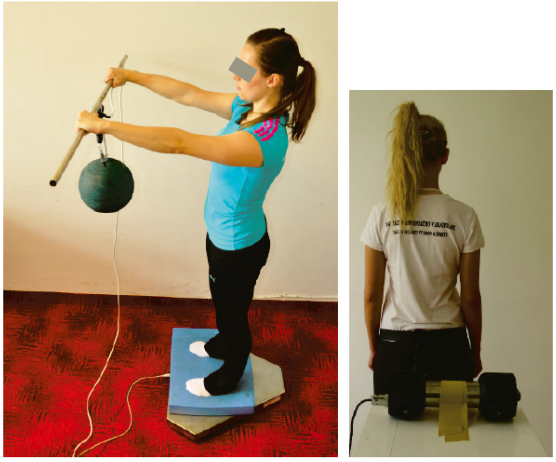

Figure 9 Perturbation-based balance test (a, b)

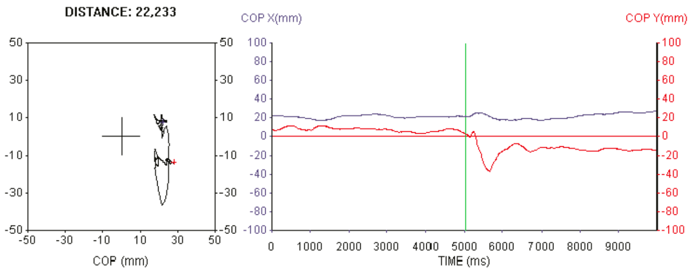

Figure 10 An example of CoP movement during the test

Assessment of postural control during a task-oriented balance test

Furthermore, task-oriented balance tests based on visual feedback control of body position can be used (Zemková, 2017b). Subjects can perform a visually-guided CoM tracking task or a visually-guided CoM target-matching task. In the first test, subjects are provided with feedback on the CoM displacement on a computer screen while standing on a force plate (Figure 11). Their task is to trace, by shifting their CoM, a curve flowing either in horizontal direction (regulation of COM movement in Y-axis) or vertical direction (regulation of CoM movement in X-axis). The deviation of an instant CoP position from the curve is recorded at 100 Hz by means of the FiTRO Sway Check system (FiTRONiC, Slovakia). The analysis of repeated measurements showed a test-retest correlation coefficient of 0.83 and a measurement error of 7.0% (Zemková, Hamar, 2010). This reliability is comparable to static balance tests, however with better potential for the differentiation between groups with different levels of postural control (Hamar, Zemková, 2009). Providing visual feedback in more demanding conditions (i.e. the stance on a spring-supported platform) enhances discriminatory accuracy of a visually-guided CoM tracking task.

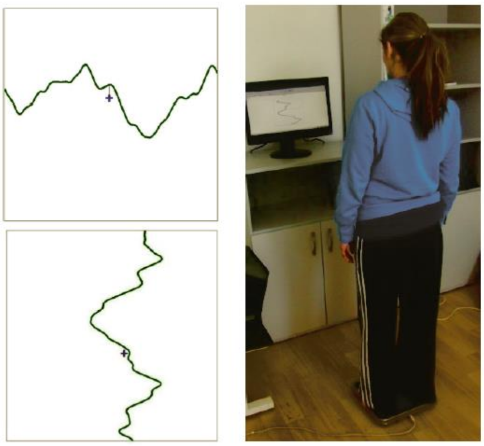

Figure 11 Task-oriented balance test

Assessment of maximal isometric back extensor muscle strength

Above mentioned tests of postural and core stability can be completed by measurement of strength of back muscles. Before the test begin, participants warm up by doing two submaximal isometric trials so as to become accustomed to the testing procedure. They are then placed into the appropriate position, based upon the knee and hip angles (141° and 124°, respectively) that are set up by a handheld goniometer. This position corresponds to the portion of the clean lift where the highest power is produced (Garhammer, 1993). Once the participant is in the position, he/she initiate the exercise after a countdown "3, 2, 1, pull." Participants perform three maximal voluntary contractions (MVCs) as forcefully and as quickly as possible for a minimum of 3 s. They are given verbal encouragement at each contraction. At least 2 min of rest is provided between MVC efforts. The instantaneous force is displayed in real time as visual feedback on a monitor positioned in front of the examiner. Force is measured by means of the FiTRO Back Dynamometer (FiTRONiC, Slovakia) (Figure 12). Analogue signals are AD converted and sampled by the computer at the rate of 1,000 Hz. The device consists of a handlebar attached to a floor-mounted load cell. The height of the handlebar above the floor is established for each individual during familiarization trials. Peak force and peak rate of force development (RFD) are analyzed.

Findings of recent study indicate that the ability of subjects to develop a high force in a short time during MVC of the back muscles may be predictive of the magnitude of trunk (expressed by CoM measures) and postural (expressed by CoP measures) displacements *induced* by an external *perturbation (*Zemková et al., 2019a). *However, greater back muscle strength (expressed by peak isometric force) does not* contribute to better core and/or postural stability. Thus, associations of measures of the perturbation based balance test and peak RFD but not peak force obtained from MVC of the back muscles in sedentary individuals indicate that the former variable should be preferred over maximal strength of back muscles in the assessment of subject's ability to maintain core and postural stability after an unpredictable perturbation.

The peak RFD obtained from MVC of the back muscles also significantly correlates with power produced during a deadlift to high pull with lower weights (Zemková et al., 2019b). The strong relationship between the ability to develop a high force in a short time and the power performance during a lifting task implies that gains in RFD after the exercise program may be related to the increase in lifting performance at light loads. These findings also indicate that peak RFD obtained from MVC of the back muscles may be predictive of power performance during a lifting task. However, one needs a high isometric maximum strength of the back muscles for great power production when lifting higher weights. Therefore, besides MVC peak force produced by back muscles, the ability of subjects to develop a high force in a short time should be evaluated in order to gain deeper insight into a loaded lifting performance in a form of a deadlift to high pull exercise (Zemková et al., 2016a).

Figure 12 Test of maximal isometric strength of back muscles

Assessment of muscular endurance of back muscles using the Sørensen fatigue test

In the Sørensen fatigue test (Biering-Sørensen, 1984) the participant lies on the Roman chair in the prone position with the upper edge of the iliac crests aligned with the edge of the chair. The feet are fixed to the device. The test starts with the upper body sloping downward toward the floor, so a concentric contraction of the trunk-extensor muscles is needed initially to reach the horizontal position. Then the participant is asked to isometrically maintain the upper body in a horizontal position while holding the arms folded across the chest. The horizontal position of the upper body is visually controlled by the examiner. The time during which the subject keep the upper body straight and horizontal is recorded. The test is stopped when the trunk is downsloping by more than 5° to 10°. In those who experience no difficulty in holding the position, the test is stopped after 240 seconds.

In the dynamic version of the Sørensen fatigue test, called the repetitive arch-up test, the participant also lies on the Roman chair in the prone position with the upper edge of the iliac crests aligned with the edge of the chair. Arms are folded across the chest, and the ankles and thighs are fixed to the device. The test starts with the upper body sloping downward toward the floor so a concentric contraction of the trunk extensor muscles is needed initially to reach the horizontal position. Participants are asked to raise the upper body upwards to a horizontal position and back down to a 45° angle. They perform each repetition in a cadence of 2-3 seconds. The horizontal position of the upper body is visually monitored by the examiner.

Hyperextension is not permitted. The number of repetitions is recorded until the participant is unable to continue.

Recent study revealed that force feedback plays a role in the ability to differentiate the strength of back muscle contraction, regardless of fatigue induced by the isometric back extension endurance test (Zemková, Jeleň, 2019). It contributes to a more precise regulation of the force produced during a voluntary isometric contraction of the back muscles. A moderate correlation between peak force and an estimated target force and a poor correlation between the time achieved in the Sørensen fatigue test and an estimated target force suggest that these methods assess distinct qualities and therefore should be tested complementarily. Although this method appears to be promising for individuals with a predominantly sedentary lifestyle, further studies are needed to investigate whether it can be also applied for those suffering from low back pain.

Conclusion

This study has shown a methodological approach to assessing postural and core stability using portable diagnostic systems that can be used in field conditions. These tests have been documented to be reliable and sensitive in revealing within- and between-group differences in body balance and strength of back muscles, as well as their changes after exercise programs. They can be included in functional performance testing of healthy college graduate students and office workers with a prevalently sedentary lifestyle, as well as highly resistance-trained athletes and construction or healthcare workers with job demands based on good postural and core stability. Alternatively, they can be applied for healthy individuals who may benefit from testing by predicting the risk of low back pain.

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REFERENCES:

ARIFIN, N. - ABU OSMAN, N. A. - WAN ABAS, W. A. Intrarater test-retest reliability of static and dynamic stability indexes measurement using the Biodex Stability System during unilateral stance. Journal of Applied Biomechanics, 2014, 30(2), 300-304. doi: 10.1123/jab.2013-0130

BIERING-SØRENSEN, F. Physical measurements as risk indicators for low-back trouble over a one-year period. Spine, 1984, 9(2), 106-119. doi:10.1097/00007632-198403000-00002

EBENBICHLER, G. - DOBLHAMMER, S. - PACHNER, M. et al. Impairments in postural control and re-test reliability of dynamic posturographic measures after lung transplantation. American Journal of Physical Medicine & Rehabilitation, 2019, 98(5), 353-359. doi: 10.1097/PHM.0000000000001095

GARHAMMER, J. A review of power output studies of Olympic and powerlifting: methodology, performance prediction, and evaluation tests. Journal of Strength and Conditioning Research, 1993, 7(2), 76-89.

HAMAR, D. - ZEMKOVÁ, E. Assessment of balance: from theoretical background to practical applications. Journal of Sports Science and Medicine, 2009, 8(suppl. 11), 30-31.

JANURA, M. - BIZOVSKÁ, L. - SVOBODA, Z. et al. Assessment of postural stability in stable and unstable conditions. Acta of Bioengineering and Biomechanics, 2017, 19(4), 89-94.

JAWORSKI, J. - AMBROŻY, T. - LECH, G. et al. Absolute and relative reliability of several measures of static postural stability calculated using a GYKO Inertial Sensor System. Acta of Bioengineering and Biomechanics, 2020, 22(2), 1-14. doi: 10.37190/ABB-01502-2019-0

JØRGENSEN, M. B. - SKOTTE, J. H. - HOLTERMANN, A. et al. Neck pain and postural balance among workers with high postural demands - a cross-sectional study. BMC Musculoskeletal Disorders, 2011, 12(176), 1-7. doi: 10.1186/1471-2474-12-176.

LEHNERT, M. - SVOBODA, Z. - CHMELIK, F. et al. Isokinetic strength of knee extensors is associated with balance in middle-aged women. The Anthropologist, 2017, 30(2), 161-166.

ODDSSON, L. I. E. - KARLSSON, R. - KONRAD, J. et al. A rehabilitation tool for functional balance using altered gravity and virtual reality. Journal of Neuroengineering and Rehabilitation, 2017, 4(25), 2-7. doi: 10.1186/1743-0003-4-25

REEVES, N. P. - NARENDRA, K. S. - CHOLEWICKI, J. Spine stability: the six blind men and the elephant. Clinical Biomechanics (Bristol, Avon), 2007, 22(3), 266-274. doi:10.1016/j.clinbiomech.2006.11.011

SHERAFAT, S. - SALAVATI, M. - EBRAHIMI TAKAMJANI, I. et al. Intrasession and intersession reliability of postural control in participants with and without nonspecific low back pain using the Biodex Balance System. Journal of Manipulative and Physiological Therapeutics, 2013, 36(2), 111-118. doi: 10.1016/j.jmpt.2012.12.005

SILFIES, S. P. - CHOLEWICKI, J. - REEVES, N. P. et al. Lumbar position sense and the risk of low back injuries in college athletes: a prospective cohort study. BMC Musculoskeletal Disorders, 2007, 8(1), 129. doi:10.1186/1471-2474-8-129

VALKOVIČ, P. - ŠTEFÁNIKOVÁ, G. - KOVÁČIKOVÁ, Z. et al. Static and task-oriented balance tests in early stages of Parkinson´s disease. Parkinsonism & Related Disorders, 2012, 18(Suppl. 2).

ZEMKOVÁ, E. - HAMAR, D. Spoľahlivosť stabilografických parametrov na dynamometrickej platni. Telesná výchova & šport, 2002, 12(2), 28-30.

ZEMKOVÁ, E. - HAMAR, D. - BÖHMEROVÁ, Ľ. Effect of three months of serial mechanical proprioceptive stimulation on parameters of balance in older women. Medicina Sportiva, 2007, 11(4), 97-101.

ZEMKOVÁ, E. The acute and long-term effect of different sensorimotor exercises on neuromuscular performance. Medicina Sportiva, 2009, 13(2), 67-73.

ZEMKOVÁ, E. - VLAŠIČ, M. The effect of instability resistance training on neuromuscular performance in athletes after anterior cruciate ligament injury. Sport Science, 2009, 2(1), 17-23.

ZEMKOVÁ, E. Sensorimotor exercises in sports training and rehabilitation. In: Duncan, M. J. - Lyons, M. (Eds). Trends in Human Performance Research. New York: Nova Science Publishers, Inc., 2010, 79-117.

ZEMKOVÁ, E. - HAMAR, D. Reliability and sensitivity of the test based on visually-guided COM tracking task. Acta Facultatis Educationis Physicae Universitatis Comenianae, 2010, 50(1), 75-85.

ZEMKOVÁ, E. Significantly and practically meaningful differences in balance research: P values and/or effect sizes? Sports Medicine, 2014, 44(7), 879-885. doi: 10.1007/s40279-014-0185-7

ZEMKOVÁ, E. - MUYOR, J. M. - ŠTEFÁNIKOVÁ, G. Nestabilné podmienky diferencujú fyzicky aktívnych jedincov a so sedavým spôsobom života s rôznou úrovňou stability postoja a trupu. Medicina Sportiva Bohemica & Slovaca, 2015, 24(3), 147.

ZEMKOVÁ, E. - CEPKOVÁ, A. - UVAČEK, M. et al. A new method to assess the power performance during a lifting task in young adults. Measurement, 2016a, 91, 460-467. doi.org/10.1016/j.measurement.2016.05.077

ZEMKOVÁ, E. - HAMAR, D. - KIENBACHER, T. et al. Clinical applications of posturography: from research to practice. Slovak Journal of Health Sciences, 2016b, 7(2), 59-77.

ZEMKOVÁ, E. - KOVÁČIKOVÁ, Z. - JELEŇ, M. et al. Postural and trunk responses to unexpected perturbations depend on the velocity and direction of platform motion. Physiological Research, 2016c, 65(5), 769-776.

ZEMKOVÁ, E. - KYSELOVIČOVÁ, O. - UKROPEC, J. et al. Unique functional performance testing for the overweight and obese. Medicina Sportiva Practica, 2016d, 17(1), 1-8.

ZEMKOVÁ, E. - ŠTEFÁNIKOVÁ, G. - MUYOR, J. M. Load release balance test under unstable conditions effectively discriminates between physically active and sedentary young adults. Human Movement Science, 2016e, 48, 142-152. doi: 10.1016/j.humov.2016.05.002

ZEMKOVÁ, E. Assessment of power and strength of trunk muscles: from the lab to the field. Scientific Review of Physical Culture, 2017a, 7(4), 103-117.

ZEMKOVÁ, E. Functionally directed balance testing: Are task-oriented balance tests a future? Collegium Antropologicum, 2017b, 41(4), 383-389.

ZEMKOVÁ, E. – HAMAR, D. – KIENBACHER, T. et al. Assessment of core stability and strength: from theory to practical applications. Slovak Journal of Health Sciences, 2017a, 8(2), 64-81.

ZEMKOVÁ, E. - JELEŇ, M. - KOVÁČIKOVÁ, Z. et al. Balance performance during perturbed standing is not associated with muscle strength and power in young adults. Journal of Motor Behavior, 2017b, 49(5), 514-523. doi: 10.1080/00222895.2016.1241751

ZEMKOVÁ, E. - KYSELOVIČOVÁ, O. - JELEŇ, M. et al. Three months of resistance training in overweight and obese individuals improves reactive balance control under unstable conditions. Journal of Back and Musculoskeletal Rehabilitation, 2017c, 30(2), 353-362. doi: 10.3233/BMR-160585

ZEMKOVÁ, E. - KYSELOVIČOVÁ, O. - JELEŇ, M. et al. Unilateral stability and visual feedback body control improves after three-month resistance training in overweight individuals. Journal of Motor Behavior, 2017d, 49(4), 398-406. doi: 10.1080/00222895.2016.1219307

ZEMKOVÁ, E. Science and practice of core stability and strength testing. Physical Activity Review, 2018, 6, 181-193. doi: 10.16926/par.2018.06.23

ZEMKOVÁ, E. - HAMAR, D. Sport-specific assessment of the effectiveness of neuromuscular training in young athletes. Frontiers in Physiology, 2018, 9, 264. doi: 10.3389/fphys.2018.00264

ZEMKOVÁ, E. - ANDREEVA, A. - HAMAR, D. Discriminatory accuracy of balance tests improves under altered stance support conditions. Smolenice: 8th International Posture Symposium, 2018, 126-127.

ZEMKOVÁ, E. Funkčná diagnostika v rehabilitácii a prevencii zranení. Boskovice: František Šalé – Albert, 2019.

ZEMKOVÁ, E. - JELEŇ, M. Differentiation of the strength of back muscle contraction under fatigue: does force feedback play a role? Journal of Sport Rehabilitation, 2019, 1-7. doi: 10.1123/jsr.2018-0496 [Online ahead of print].

ZEMKOVÁ, E. - POÓR, O. - CEPKOVÁ, A. Is there an association between the back muscle strength and balance control in response to external perturbations? International Journal of Fitness, Health, Physical Education & Iron Games, 2019a, 6(2), 9-13.

ZEMKOVÁ, E. – POÓR, O. – PECHO, J. Peak rate of force development and isometric maximum strength of back muscles are associated with power performance during load-lifting tasks. American Journal of Men's Health, 2019b, 13(1), 1-8. doi: 10.1177/1557988319828622

ZEMKOVÁ, E - KOVÁČIKOVÁ, Z. - ZAPLETALOVÁ, L. Is there a relationship between workload and occurrence of back pain and back injuries in athletes? Frontiers in Physiology, 2020, 11, 894. doi: 10.3389/fphys.2020.00894

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