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Review Article

Evaluation of Human Body Balance: A Review of Clinical and Simple Field Tests of Balance

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Abstract

The purpose of this article is to highlight the main evaluation techniques used in body balance. We discussed movement regulation, biomechanical, metric characteristics, validity, objectivity, repeatability, sensitivity for the practical use of every assessment. We also identify critical research-based reviews, Pros and cons of the body balance tests. The techniques are widely used in rehabilitation, sports medicine, and laboratory. The article closes with a summary of human balance and proposals for future research work.

Keywords: human body balance, validity, objectivity, and sensitivity

Human Body Balance

Andrej Panjan and Nejc Sarabon described balance as a fundamental ability of human movement. Maintaining balance during anti-gravitational activities as well as proper body posture represent a groundstone for the execution of other secondary movements. Winter et al. 1995 stated that we used to propel ourselves through space or manipulate the surrounding environment. Among the elderly individuals, numerous works of literature described that evaluation of human balance body is fragile due to the increased risk of falling. Falls represent one of the most serious health problems in elderly populations.

In sports medicine, balance in sports has a connection with injury development and this can affect the body balance. The ability to achieve the utmost athletic skill required good balance (De Noronha et al. 2006). Studies conducted by Gage et al.2006 identified different sports activities that required good balance such as gymnastics, football, and hockey, etc. Sarabon et. al 2010, mechanically defined balance as the ability to sustain the center of body mass in limits of the support surface. The ability of a person to lose these properties resulted in to fall. Thereafter, support will now be required. The support surface can be defined by the area between the feet or with the area of the ground on which a person stands. Our bodies maintain balance using different strategies.

Winter, 1995 identified two main areas in the body responsible for balance strategy is hip and ankle. The first strategy involves when the support surface perturbation to balance is bigger. The other strategy is used to compensate for rotational or smaller perturbations. The difference between the strategies is simpler movements. As the intensity of balancing increases, they seem to work in synchrony, compensating for various types of perturbations or enabling the execution of more demanding skills (Bardy, Oullier, Bootsma, & Stofrregen, 2002).

There are two training techniques called balance and proprioception of sensorimotor training (Lephart, Riemann, & Fu, 2000). These techniques provide the rationales for a better understanding of balance. Balance can be assessed whether good or poor in an uninjured athlete, the elderly population (Karinkanta et al. 2010). The second rationale provided by the consensus of sports science 2010 review advises us to assess balance in athletes as poor balance can have a negative effect on specific sports skills. The ability to quantify balance deficits and training improvements methods used in clinical as well as in sports Practice. We used different methodologies, technology and differ in the level of balance assessment. Basic differences must be considered when coaches, clinicians, or therapists decide which of the methods is most appropriate to apply to their specific demands. In the following division, we will first begin with insight into the basic metric characteristics of the tests. Then followed by an expository view of frequently used clinical and simple field tests of balance; laboratory tests; and moreover, techniques and parameters used to assess static balance; and laboratory tests of dynamic balance. The basic importance of each test will be described and additionally, pros and cons will be pointed out.

Methods for the Evaluation of Human Balance Body

There are various methods used for the assessment or evaluation of human body balance. Balance measuring protocol will be observed such as reliability which represents the variation measured. This is also known as consistency.

There are four various forms of reliability: parallel-forms reliability and internal consistency reliability, inter-rater and inter-observer reliability, test-retest reliability and parallel-forms reliability is used to assess the consistency of the results of two tests constructed in the same way from the same content domain. It could be used to select the best test among the selected tests for the same, i.e., presumably alike, functional ability. This, however, does not necessarily mean that this test is the best for the specific problem. Inter-rater reliability is used to assess the degree to which different raters/examiners give consistent estimates of the same phenomenon. Balance testing is usually performed by various examiners, making it important to be aware of possible errors resulting from poor inter-rater reliability. Test-retest reliability is used to assess the consistency of a measure from one time to another. This is simply the reliability between two or more trials performed by the same examiner on the same subject. This type of reliability is most frequently examined in the evaluation of body balance, equilibrium, and posture assessment methods. Internal Consistency reliability is used to assess the consistency of results across subjects within the test. It could be used to test the reliability of a specific measure of the test across a group of subjects. The most commonly used coefficients of reliability are intra-class correlation coefficient (ICC) and coefficient of variation (CV). The validity of a test is described as the test's relevance degree to which the tool measures what it claims to measure. It can be evaluated by comparing the results obtained by a tested test with a gold standard test for a specific problem. Validity is expressed as correlation coefficients between the two. If the balance test is not valid it cannot be used in balance and equilibrium assessment. Sensitivity is a factor that can detect small, but important, changes in the performance of a subject. The difference between finishing as first or second can be very small in a sports event like a sprint. For example, balance tests should be sensitive to small changes in balance tasks used, like different feet positions. By these means, important differences in the function of balance mechanisms can be evaluated (Sarabon et al., 2010). Therefore, it is important to be able to detect small changes in performance. Because every measurement is affected by noise (e.g. signals), we need to be observant to identify whether small changes are changes in performance or just a result of noise. A quantitative value of sensitivity may be obtained by comparing results of the measurement-to-noise ratio, where the results are the percentage improvement in performance and the noise is the CV. To sum up, when considering which balance testing protocol to apply to sports practice, measurement equipment, and assessment procedure in general, should provide the test with good objectivity, reliability, and sensitivity. It should precisely measure the balance task, performance, or characteristic specific for a certain sub-type of balance.

Clinical and Simple Field Tests of Balance

Pérennou et al. 2005 identified clinical and simple field tests of human balance are tests that require none or little equipment, are very cheap and can be performed quickly. The different number of tasks that are evaluated either using a score on a predefined qualitative scale, counting balance loses or simple time measurements. The tests are performed on a subject whose quality of executing different tasks is evaluated by an expert. These assessment procedures are based on standardized test protocols; however, they remain to be influenced by a human factor (subjectivity) since they are based on the observational criteria of the examiner. The more difficult tests (Flamingo test, sharpened Romberg test, etc.) are also used in sports testing and screening protocols, while the less demanding ones have been frequently reported in the studies focusing on the elderly adult population who are at risk for falls such as berg balance score (BBS).

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Romberg Test: The test is based on the premise that a person requires at least two of the three underlying body senses, which are crucial for the maintaining of equilibrium while standing, namely proprioception (the ability to know one's body in space), exteroception (the ability to feel touch or pressure) and vision (which can be used to monitor balance changes). A subject who has a problem with proprioception can still maintain balance by using exteroceptive sensation and vision. The Romberg test is a test of the body's sense of positioning (proprioception), which requires healthy functioning of the dorsal columns of the spinal cord (Khasnis & Gokula, 2003). Besides balance testing, it is also used as an indicator for possible alcohol or drug-impaired driving and neurological decompression sickness. To perform the test, the subject is asked to stand erect with feet together and eyes closed. It is recommended that the examiner or assistant stand close to the subject as a precaution to stop him from falling over and hurting himself/herself. Watch the movement of the body in relation to a perpendicular object behind the subject (corner of the room, door, window, etc.). A positive sign is noted when a swaying, sometimes irregular swaying and even toppling over occurs. The essential feature is that the subject becomes more unsteady with eyes closed. First, the subject stands with feet together, eyes open and hands by the sides. Then the subject closes the eyes while the examiner observes for a full minute. Romberg's test is positive if the subject sways or falls while the subject's eyes are closed (Lanska & Goetz, 2000). Subjects with a positive result are said to demonstrate Romberg's sign. They can also be described as Romberg's positive. The basis of this test is that balance arises from the combination of several neurological systems, namely proprioception, vestibular input, and vision. If any two of these systems are working, the subject should be able to demonstrate a fair degree of balance. The key to the test is that vision is taken away by asking the subject to close their eyes. This leaves only two of the three systems remaining and if there is a vestibular disorder (labyrinthine) or a sensory disorder (proprioceptive dysfunction), the subject will become much more imbalanced.

The sharpened Romberg test (Sofianidis, Hatzitaki, Douka, & Grouios, 2009), also known as the tandem stance test (Fitzgerald, 1996) was developed based on Romberg test. In this case, a subject is asked to stand heel-to-toe (tandem position) with their arms crossed so that the open palm falls across the opposite shoulder. The subject closes his eyes once he is stable. He tries to maintain this position for a full minute. Evaluation is the same as with Romberg test. Under sharpened Romberg test also other stands (semi tandem, contra tandem, one leg and/or additional equipment Band, Gymnic, and some other balance pads are used to increase the difficulty of the task. Poor sensitivity of the sharpened Romberg test was reported by Šarabon & Omejec (2007) who carried out a study on 102 healthy young subjects. The same study revealed a moderate level of test-retest repeatability of the Romberg test.

The five different foot positions used in SRT: parallel, semi tandem, tandem, contralateral tandem, and single leg. D (dominant leg) and ND (non-dominant leg) mark the leg dominance. Tinetti balance test (Young, & Kostyk, 2010.) is an easily administered test to measure a subject's gait and balance ability. The test is used to evaluate the subject's ability to perform specific tasks and is primarily used as a predictive measure for falls. Most commonly it is used on the elderly adult population who are at most risk for falls, and it takes approximately 10 to 15 minutes to perform and score. The test is performed in two parts – a balance and a gait part. The subject is asked to perform very specific tasks listed and described on the assessment tool form. The therapist observes the completion of each task and scores the subject on a 0-2 scale based on how the task is completed. Score 0 represents the most impairment, while a 2 would represent the independence of the subject. At the end of each part, the therapist adds up the subjects total score and compares it to the test pre-assessed ranges. The total possible score for the balance part is 16 points and the total possible score for the gait part is 12 points. Subjects who score a total of 19 points or below are at high risk for falls, while subjects who score between 19 and 24 points have a moderate risk for falls and subjects with scores above 24 points are at limited risk for falls. Tools needed for this assessment include a chair, a stopwatch, and a 5-meter walkway.

Inter-rater and intra-rater reliability of the test was performed on individuals with amyotrophic lateral sclerosis (Kloos et al., 2004). High ICC values (> 0.90) were found for the total Tinetti test scores. Interrater reliability between three experts was 88% for individual maneuvers, while intra-rater reliability of 93% was observed for 6 experts. The results suggest that the Tinetti test is reliable for examination of this specific group of individuals.

The Berg balance scale (BBS) or Berg balance test (Greene et al., 2010) was developed to measure balance among older people with impairment in balance function by assessing the performance of functional tasks. It is a valid instrument used for the evaluation of the effectiveness of interventions and for quantitative descriptions of function in clinical practice and research. The BBS consists of 14 tests (each has a five-point scale 0-4) designed to measure the balance of the older adult in a clinical setting. Equipment needed includes a ruler, two standard chairs (one with armrests, one without), a footstool or step, a stopwatch or wristwatch, and a 5-meter walkway. It takes 15 to 20 minutes to perform the test on one subject. Subjects who achieved 0-20, 21-40 and 41-56 are at high, medium, and low risk of falling, respectively. The BBS has been evaluated in several reliability studies.

Many studies of the BBS indicate that a change of 8 BBS points is required to reveal a genuine change in function between two assessments among older people. Bogle Thorbahn and Newton (1996) conducted a study on elderly people in which they wanted to determine whether the Berg balance test could be used to predict an elderly person's risk of falling. Although the Berg balance test demonstrated only 53% sensitivity, the results support the test developers' use of 45 (out of 56) as a generalized cutoff score. Older adults who scored higher than the cutoff score on the test were less likely to fall than were those adults who scored below the cutoff score. Decreased scores, however, did not predict an increased frequency of falls.

Study with the aim to determine test-retest reliability and minimal detectable change for the BBS, the Romberg Test (RT), and the Sharpened Romberg Test (SRT) with eyes open and closed was carried out on elderly people with Parkinsonism. The ICCs for test-retest reliability were above 0.90 for the BBS and SRT with eyes closed. The minimal detectable change values (calculated using a 95% confidence interval) were 5/56 for BBS and 19 seconds for SRT with eyes closed. Minimal detectable change values are useful to therapists in rehabilitation and wellness programs in determining whether change during or after an intervention is clinically significant.

The Flamingo balance test (Douda, & Tokmakidis, 2002) achieves the requirements of simplicity, low cost, and it is proper for mass investigations. It is used to assess the ability to balance successfully on a single leg. This test is more difficult than the ones described above, and it is most commonly used as a field motor test of balance on healthy subjects or athletes. Only a stopwatch and a narrow beam (5 cm) with a non-slip surface are necessary to perform the test. Sometimes the test is performed on a wide surface and not on the beam. In this test the subject is standing on a beam on his preferred foot, bends his free leg backward and grips the back of the foot with the hand on the same side, standing like a flamingo. The procedure is as follows: start the stopwatch when the subject is in a described pose, stop the stopwatch each time the subject loses balance (let go of the foot being held), start timing again until he loses balance and counts the number of falls in 60 seconds of balancing. If there are more than 15 falls in the first 30 seconds, the test is terminated and a score of zero is given. Poor sensitivity of the test was reported in a study on young healthy people, due to a large number of subjects achieving the best results possible (Sarabon & Omejec, 2007). Also, moderate repeatability (ICC = 0.61) was observed in the same study. Stabilometry of the flamingo test was assessed in the study performed by Barabas, Bretz and Kaske (1996). They conclude that stabilometry in the Flamingo test position differentiates better the athletes with a high level of balance capabilities than the traditional Romberg test. In the section about clinical and simple field tests of human balance, few studies about the prediction of a person's risk of falling were pointed out.

Laboratory Tests of Static Balance

The static balance of the human body is the ability to maintain a specific posture.

This is obtained in a standing subject with devices that measure the movements of the body or its center of gravity, or mostly the center of pressure (COP). At first, mechanical or magnetic recording devices connected to the waist (Lord, Clark, & Webster, 1991) or the hip region (Dean, Griffiths, & Murray, 1986) were used. Today the most common device is a force platform (Raymakers 2005) which measures the COP of the whole human body, rather than just a segment, as previously mentioned devices. There are many possibilities of quantifying the COP path of body sway.

An extensive review of parameters that were used to assess body sway is presented in the rest of this section. Example of static balance test on a force plate (single leg stance, eyes closed, arms free). An example of the COP sway of this test is on the right side. Acquisition and signal processing of the COP sway is an essential part of a test. Usually, manufacturers of force plate systems offer software for the acquisition of the COP, but we should still pay attention to the sampling frequency of the acquisition. If it is too low, then we might not be able to acquire small and high-frequency changes of the COP.

The recommended sampling frequency is between 100 and 1000 Hz. Higher sampling frequencies are not necessary and they will only increase the amount of data acquired. Processing of acquired data consists of preprocessing and actual processing where final results are computed. Preprocessing usually consists of the detection of outliers and data filtering. The latter is especially important when we acquire an analog signal (e.g. COP components from the force plate). For mechanical signals, bandpass filters with cutoff frequencies of 0.1 and 15 Hz should be used because human is not able to surpass this frequency while moving. Many different parameters of COP sway have been proposed over the years. In general, we can classify them into two main categories; global and structural (Baratto, Morasso, Re, & Spada, 2002). Global parameters estimate the overall size of the COP sway, while structural parameters estimate the elements or smaller parts of the COP sway. Regarding the direction, parameters can be calculated as two-directional and/or one-directional, where the anterior-posterior (AP) and the mediolateral (ML) are the two possible directions. The whole set of parameters known from literature is listed and described in a table that includes name, symbol, unit, directions and description of the parameter. Global parameters of COP sway Structural parameters are divided into parameters based on the computation of diffusion plots or variograms proposed by Collins et al. (1993, 1995a, 1995b), and on parameters based on the analysis of sway density plots proposed by Jacono, Casadio, Morasso and Sanguineti (2004).

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Laboratory Tests of Dynamic Balance

Dynamic body balance is required for normal daily activities, such as walking, running, and stair climbing. Sports activities also require proper balance control.

Dynamic body balance is the ability to maintain balance while moving, such as running, tumbling, or walking. It can be maintained either on a moving surface or while the body is moving. The assessment of dynamic body balance during walking or running is even nowadays rather an exception than a rule.

The reason probably lies in the fact that the equipment needed for such an experiment is more advanced, but on the other hand, there has been very little research work done regarding this area, and no standards were proposed. All commonly used tests of dynamic balance are more or less simple, except tests on specially designed machines (namely EquiTest® and Biodex Balance System SD) that are quite expensive. In the following sections, we present all regularly used tests in the latest studies. Figure 4. Example of dynamic balance test – Clever balance board. Analysis of the test and parameters calculation is performed by a microprocessor installed in the device. The Star Excursion Balance Test (SEBT) is a functional test that incorporates a single-leg stance on one leg (e.g. right leg) whilst trying to reach as far as possible with the opposite leg (e.g. left leg). The participants stand in the center of the grid with 4 lines at 45° between adjacent ones, forming a star-like shape.

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SEBT test directions for left leg stance (AL - anterolateral, A - anterior, AM - antero-medial, M - medial, PL - postero-medial, P - posterior, PL - postero-lateral and L – lateral).

There are 8 individual directions possible and the subject is required to reach out in these directions with the most distal part of his reach foot. The eight directions consist of antero-lateral, anterior, antero-medial, medial, posteromedial, posterior, postero-lateral and lateral. A standard tape measure or a force plate can be used to quantify the distance the subject had reached from the center of the grid to the point that the subject managed to reach along each diagonal line. The reliability of the test was performed on young healthy subjects who performed 12 sessions with five trials to gain an ICC of 0.86 (Kinzey & Armstrong, 1998).

According to the number of studies that included SEBT, it is the most frequently used test of dynamic body balance – for review see: Herrington, Hatcher, Hatcher and McNicholas, 2009; Plisky, Rauh, Kaminski and Underwood, 2006; Sabin, Ebersole, Martindale, Price and Broglio, 2010. The Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) (Cushing, Chia, James, Papsin, & Gordon, 2008; Deitz, Kartin, & Kopp, 2007; Levine, 1987 is an individually administered test designed to assess motor skills in children ranging in age from four and 1/2 to fourteen and 1/2 years of age. It has been described as the most outstanding instrument of its kind, and one which fills a clinical void.

The BOTMP is widely used by occupational therapists, educators, and psychologists and is often considered a necessary part of diagnostic testing, especially for children with learning disabilities. This individually administered test includes 46 items, grouped into eight subtests. Subtests include: running speed and agility, balance, bilateral coordination, strength, upper-limb coordination, response speed, visual-motor control, and upper-limb speed and dexterity. Items are arranged into three composites and yield a comprehensive index of motor proficiency as well as separate measures of gross and fine motor skills. For each of these composites, normalized standard scores, percentile ranks, and stanines are available. Age equivalents are also available for the subtest scores. The entire battery takes about one hour to administer, or a short form can be administered in 20 minutes. Test-retest reliabilities for the battery composite range from 0.86 to 0.89, and the short from 0.84 to 0.87. The gross motor composite reliabilities are slightly higher than those of the fine motor composite. Gross motor reliabilities range from 0.77 to 0.85, and fine motor composite reliabilities from 0.68 to 0.88. Individual subtest scores range from 0.29 to 0.89 and must be interpreted with extreme caution, if at all.

Functional Reach Test (FRT) (Duncan, Weiner, Chandler, & Studenski, 1990) is a single item test developed as a quick screen for balance problems in older adults. To perform the test a subject must be able to stand independently for at least 30 seconds without the support and be able to flex the shoulder to at least 90 degrees. A stick is attached to a wall at about shoulder height. The subject is positioned in front of the stick and the examiner is about 2 to 3 meters away from the subject, viewing the subject from the side. The subject is instructed to stand with feet at shoulder distance apart and make a fist and raise the arm so that it is parallel to the floor. At this time, the examiner takes an initial reading on the stick, usually spotting the knuckle of the third metacarpal. The subject is instructed to reach forward along with the stick without moving the feet. Any reaching strategy is allowed but the hand should remain in a fist. The examiner takes a reading on the stick of the farthest reach attained by the subject without taking a step. The initial reading is subtracted from the final to obtain the functional reach score. For subjects that are unable to stand a modified FRT was developed by Lynch, Leahy, and Barker (1998). High reliability (ICC between 0.85 and 0.94) for this test was reported. The question of whether FRT measures dynamic balance was raised in a study by Wernick-Robinson, Krebs, and Giorgetti (1999). They conclude that FRT does not measure dynamic balance. Methods for the Evaluation of Human Balance Body.

The jump-landing test is a simple test of dynamic postural stability, which can be defined as an individual's ability to maintain balance while transitioning from a dynamic to a static state (Goldie, Bach, & Evans, 1989). The test is performed on a force plate. A subject performs both leg jump, to approximately 50% of the maximal height, and lands on a single leg. After landing, the subject remains motionless in a single leg stance for a predefined time (usually from 10 to 30 seconds). Several parameters can be calculated for this test. The most common parameter calculated is the time to stabilization (Brown, Ross, Mynark, & Guskiewicz, 2004; Ross & Guskiewicz, 2003, 2004). The time to stabilization is defined as the time required to minimize the resultant ground reaction forces of a jump landing within a range of the baseline (static) ground reaction forces. As an aspect of motor control for the lower extremity, time to stabilization depends on proprioceptive feedback and preprogrammed muscle patterns, as well as reflexive and voluntary muscle responses (Johnston, Howard, Cawley, & Losse, 1998). Another parameter for the jump-landing test is the dynamic postural stability index (Wikstrom, Tillman, Smith, & Borsa, 2005). This parameter is based on previous assessments of single-leg stance and single-leg hop stabilization tests with the underlying premise that dynamic postural stability depends on lower extremity kinematics at landing as well as on muscular activation patterns and eccentric control. The reliability of the time to stability and the dynamic postural stability index was assessed by Wikstrom et al. (2005). They observed higher ICC values (ICC = 0.96) for the dynamic postural stability index, while the time to stability ICC values were 0.66, 0.80 and 0.78 for mediolateral, anteroposterior, and vertical direction respectively.

A novel tool for the assessment of dynamic body balance for healthy individuals named clever balance board was presented by Sarabon, Mlaker and Markovic (2010). The clever balance board consists of two main plates connected by an axis in the horizontal plane and an angle meter attached to the axis. That allows rotation of one plate around the second one while the angle between them is measured during a test. Several parameters are calculated based on the angle waveform acquired. The reliability of these parameters was tested on a sample of 36 healthy male subjects. ICC values obtained were between 0.77 and 0.90 indicating that a clever balance board could be a reliable tool for dynamic balance assessment in healthy and physically active individuals (Sarabon et al. 2010). Active dynamic balance tracking test is a new technique for assessment of dynamic body balance invented by our group. The idea was adopted from hand grip and position tracking tasks originating from motor control studies. A force plate and special software are needed to perform this test. A random curve that has to be followed by a subject is created with software. The subject is placed on the force plate in any stance, the random curve and real the random curve as well as possible with moving his center of pressure. The random curve can move in medio-lateral or antero-posterior or both directions at the same time. Computerized dynamic photography is a quantitative method for accessing upright balance function under a variety of tasks that effectively simulate conditions in daily life (Jacobson, Newman, & Kartush, 1997). The protocols are designed to eliminate sensory, motor and biomechanical components contributing to balance. The subject's ability to maintain his balance is then analyzed. Special equipment was developed for this purpose (e.g. EquiTest, NeuroCom International and Balance System SD, Biodex) that includes different protocols of testing. Computerized dynamic photography was well researched by scientists (Mockford et al., 2010. Many studies regarding ankle stability were performed by evaluating the dynamic balance of a subject. As found by previous studies (Brown & Mynark, 2007), functional ankle stability/instability affects balance. Many studies considering this issue were conducted (Hale, Hertel, & Olmsted-Kramer, 2007; Lin, Liu, Hsieh, & Lee, 2009; Martínez-Ramírez, Lecumberri, Gómez, & Izquierdo, 2010; McKeon et al., 2008; Munn, Sullivan, & Schneiders, 2010; Ozunlu, Basari, & Baltaci, 2010).

Detrended fluctuation analysis (DFA) is a technique that characterizes the pattern of variation across multiple scales (fractal-scaling) and is based on the assumption that variations due to intrinsic dynamics of the system exhibit long-range correlations If the outcome parameter α is between 0.5 and 1, this indicates the presence of long-range power-law correlations in the time series. This technique was presented and described in detail by Peng, Havlin, Stanley and Goldberger (1995). The largest Layapunov exponent (LLE) measures the system's resistance to small internal perturbations, such as the natural sway fluctuations present while standing upright. In other words, it detects the presence of chaos in a dynamic system. Lyapunov exponents quantify the exponential divergence of initially close state-space trajectories and estimate the amount of chaos in a system (Rosenstein, Collins, De Luca, & Michael, 1993). If LLE is negative, then any perturbation exponentially damps out and initially close trajectories remain close.

In contrast, for positive LLE, nearby points diverge as time evolves and produce instability; that is when the distance between the trajectories increases exponentially. LLE was commonly used in recent studies of COP (Donker et al, 2007; Kyvelidou, Harbourne, Shostrom, & Stergiou, 2010; Kyvelidou, Harbourne, Stuberg, Sun, & Stergiou, 2009; Mizuta, Tokita, Ito, Aoki, & Kunze, 2009). The reliability of calculated parameters is important when we try to provide reliable conclusions. Because it is hard to form a well-defined sample of people (one would have to include many different people profiles: young, old, healthy, ill, etc.) and cover many static balance tests in a single study, we cannot talk about the reliability of parameters in general, but we are limited to the sample that was included in the study. Some basic metric characteristics of the test were provided along with the test description in previous paragraphs. However, for some tests we were unable to find reports about some characteristics, thus, we believe there is a gap in the research literature regarding this problem. We propose that authors of new methods provide information about the basic characteristics of the test along with the presentation of it. The same also applies to the protocol of the test. Each protocol should include a description of all essential parts (measurement procedure, arms position, elimination of vision, stance, standing surface, number of introductory trials, number of trials, randomization of tests, etc.) which importantly influence the balance.

Conclusion

In this paper, we presented a great part of the tests, methods and parameters that are used to assess the ability of human body balance. Presented tests differ in complexity, costs of equipment required, amount of time required and their purpose.

The simplest tests are clinical and simple field tests, while the most complex tests to perform are the dynamic balance tests. Similarly, the simplest methods and parameters used to evaluate balance are used for a clinical and simple field test. On the other hand, the most complex ones are used for dynamic and static balance tests. Basic metric characteristics of methods are in most cases assessed on a limited population; therefore, they cannot be considered for a general population. We propose that each new method is evaluated for all basic metric characteristics on a general population.

However, we do not disagree with the proposal of methods for the specific type of population.

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Clinical and simple field tests are today mainly used to assess balance on the elderly population and very rarely on athletes. They are not proper for athletes, because in most cases they score a maximum number of points (some more difficult tests can be an exception here). Clinical tests are widely used in risk for falls evaluation mainly on the elderly population. As sports science research devoted great attention to the studies of the elderly population and their related health and prevention issues, the majority of basic metric characteristics are assessed on this particular population. Nevertheless, evaluation of some basic metric characteristics is for some tests irrelevant (when all subjects score the maximum number of points) as reported by Sarabon and Omened (2007). Therefore, scientists have to be aware of this problem. In laboratory tests of static balance, only one technique stands out, i.e. measurement of COP sway on a force place.

Some other techniques (e.g. magnetic recording devices) can be used to measure COP sway; however, they measure only the sway of the body part to which they are attached. Many methods and parameters for the analysis of the COP sway were proposed. Some of them are quite simple (e.g. SP, SV and SA) and some of them require more knowledge about signal processing and time series analysis (e.g. SE and DFA). At this point, no method or parameter is the best in the interpretation of balance, because this depends on a problem that needs to be explained.

In general, the reliabilities of those parameters for the specific population were seldom higher than 0.90. This may indicate that only one parameter could not model balance well enough. Thus, combinations of parameters may explain (model) the behavior of balance more completely. Application of methods of machine learning or data mining tools could be useful in further research work on the human body balance.

Dynamic body balance is more complicated to evaluate than static body balance. Thus, tests require more equipment (also more advanced) and also methods are more complex than the ones used in static balance analysis. Among dynamic balance tests, there are some very simple (e.g. SBAT and FRT), mainly used for clinical practice. On the other hand, very advanced equipment (e.g. EquiTest and Balance System SD) is also used in some clinical cases and more often in research work. As mentioned previously, regarding the analysis of the COP sway, also for the analysis of dynamic body balance could be more effectively and comprehensively analyzed with the application of methods of machine learning or data mining tools.

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