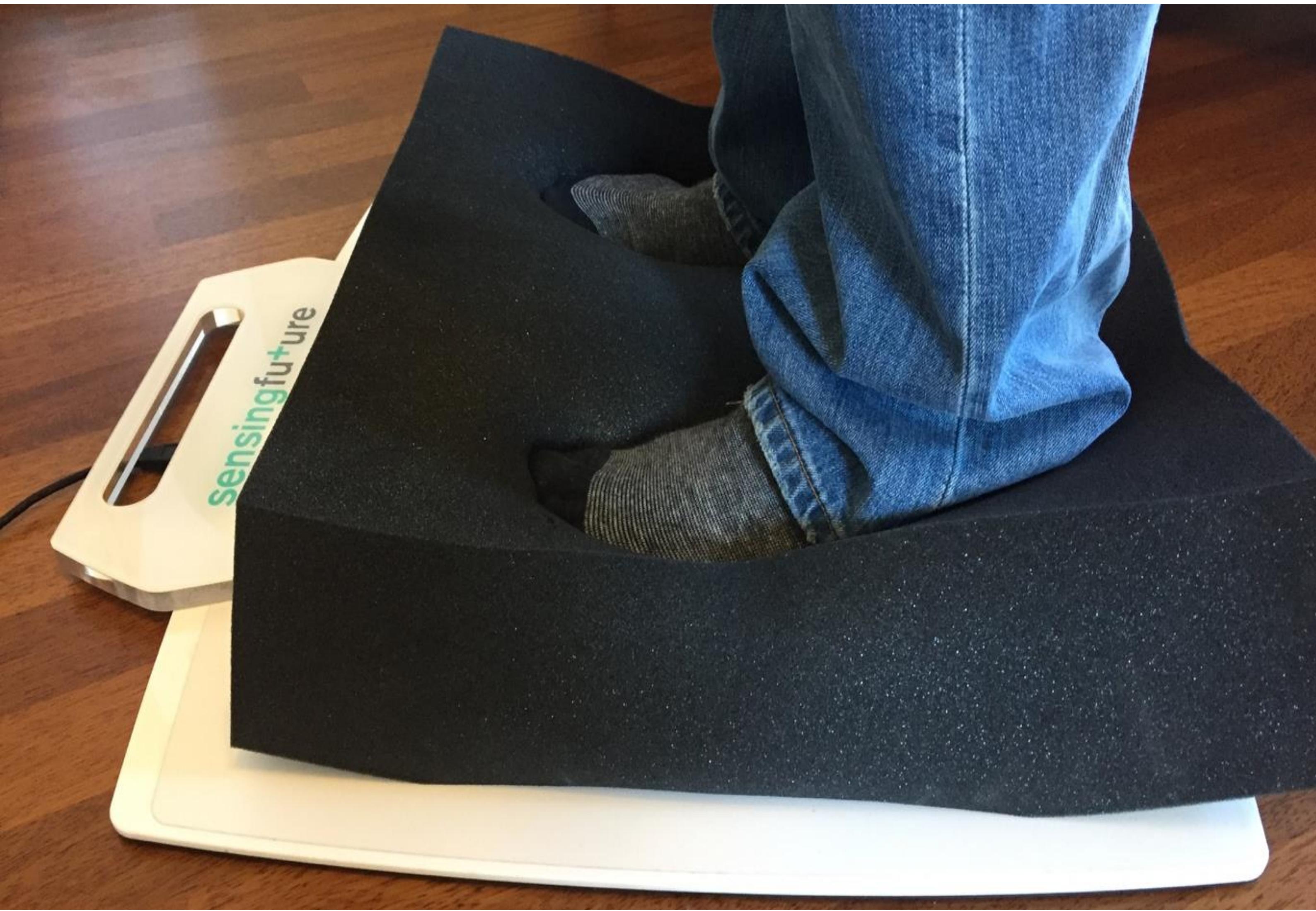
Clinical Practice Manual

BALANCE

Assessment & Training



<u>Version Manual: April 2018</u>

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1. Balance

1.1. Good balance is often taken for granted

Good balance is often taken for granted. Most people don't find it difficult to walk across a gravel driveway, transition from walking on a sidewalk to grass, or get out of bed in the middle of the night without stumbling. However, with impaired balance such activities can be extremely fatiguing and sometimes dangerous. Symptoms that accompany the unsteadiness can include dizziness, vertigo, hearing and vision problems, and difficulty with concentration and memory.

1.2. What is balance?

Balance is the ability to maintain the body's center of mass over its base of support (Figure 1). A properly functioning balance system allows humans to see clearly while moving, identify orientation with respect to gravity, determine direction and speed of movement, and make automatic postural adjustments to maintain posture and stability in various conditions and activities. Balance is achieved and maintained by a complex set of sensorimotor control systems that include sensory input from vision (sight), proprioception (touch), and the vestibular system (motion, equilibrium, spatial orientation); integration of that sensory input; and motor output to the eye and body muscles. Injury, disease, certain drugs, or the aging process can affect one or more of these components. In addition to the contribution of sensory information, there may also be psychological factors that impair our sense of balance.

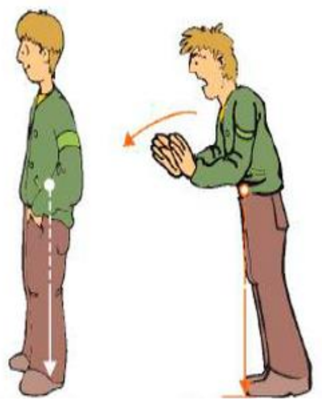


Figure 1 – Example of the center of mass in balance and outside the base of support (unstable - person will fall).

1.3. Sensory input

Maintaining balance depends on information received by the brain from three peripheral sources: eyes, muscles and joints, and vestibular organs (Figure 2). All three of these information sources send signals to the brain in the form of nerve impulses from special nerve endings called sensory receptors.

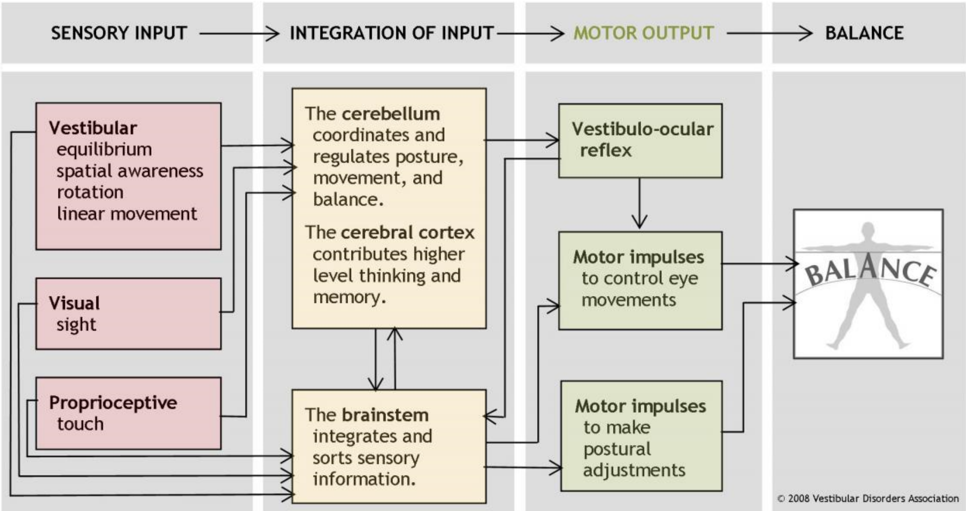


Figure 2 – The human balance system: balance is achieved and maintained by a complex set of sensorimotor control systems.

1.4. Input from the eyes

Sensory receptors in the retina are called rods and cones. Rods are believed to be tuned better for vision in low light situations (e.g. at night time). Cones help with color vision, and the finer details of our world. When light strikes the rods and cones, they send impulses to the brain that provide visual cues identifying how a person is oriented relative to other objects. For example, as a pedestrian takes a walk along a city street, the surrounding buildings appear vertically aligned, and each storefront passed first moves into and then beyond the range of peripheral vision.

1.5. Input from the muscles and joints

Proprioceptive information from the skin, muscles, and joints involves sensory receptors that are sensitive to stretch or pressure in the surrounding tissues. For example, increased pressure is felt in the front part of the soles of the feet when a standing person leans forward. With any movement of the legs, arms, and other body parts, sensory receptors respond by sending impulses to the brain. Along with other information, these stretch and pressure cues help our brain determine where our body is in space. The sensory impulses originating in the neck and ankles are especially important. Proprioceptive cues from the neck indicate the direction in which the head is turned. Cues from the ankles indicate the body's movement or sway relative to both the standing surface (floor or ground) and the quality of that surface (for example, hard, soft, slippery, or uneven).

1.6. Input from the vestibular system

Sensory information about motion, equilibrium, and spatial orientation is provided by the vestibular apparatus, which in each ear includes the utricle, saccule, and three semicircular canals. The utricle and saccule detect gravity (information in a vertical orientation) and linear movement. The semicircular canals, which detect rotational movement, are located at right angles to each other and are filled with a fluid called endolymph. When the head rotates in the direction sensed by a particular canal, the endolymphatic fluid within it lags behind because of inertia, and exerts pressure against the canal's sensory receptor. The receptor then sends impulses to the brain about movement from the specific canal that is stimulated. When the vestibular organs on both sides of the head are functioning properly, they send symmetrical impulses to the brain.

1.7. Integration of sensory input

Balance information provided by the peripheral sensory organs – eyes, muscles and joints, and the two sides of the vestibular system – is sent to the brain stem. There, it is sorted out and integrated with learned information contributed by the cerebellum (the coordination center of the brain) and the cerebral cortex (the thinking and memory center). The cerebellum provides information about automatic movements that have been learned through repeated exposure to certain motions. For example, by repeatedly practicing serving a ball, a tennis player learns to optimize balance control during that movement. Contributions from the cerebral cortex include previously learned information; for example, because icy sidewalks are slippery, one is required to use a different pattern of movement in order to safely navigate them, see Figure 3.

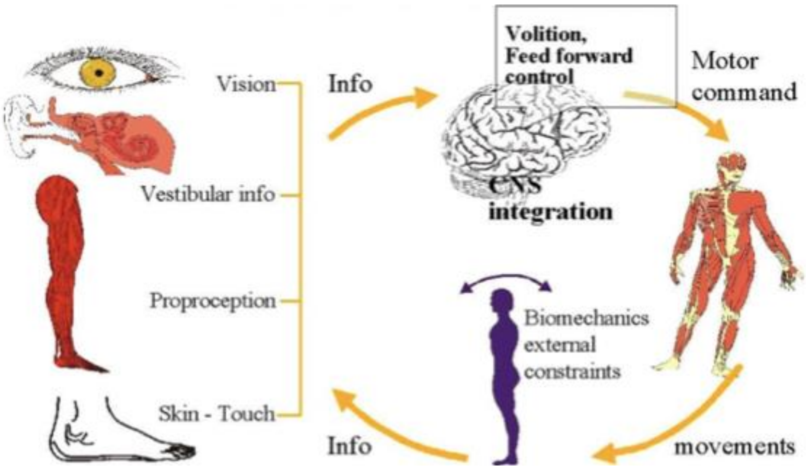


Figure 3 – Balance control system.

1.8. Processing of conflicting sensory input

A person can become disoriented if the sensory input received from his or her eyes, muscles and joints, or vestibular organs sources conflicts with one another. For example, this may occur when a person is standing next to a bus that is pulling away from the curb. The visual image of the large rolling bus may create an illusion for the pedestrian that he or she – rather than the bus is moving. However, at the same time the proprioceptive information from his muscles and joints indicates that he is not actually moving. Sensory information provided by the vestibular organs may help override this sensory conflict. In addition, higher level thinking and memory might compel the person to glance away from the moving bus to look down in order to seek visual confirmation that his body is not moving relative to the pavement.

1.9. Motor output

As sensory integration takes place, the brain stem transmits impulses to the muscles that control movements of the eyes, head and neck, trunk, and legs, thus allowing a person to both maintain balance and have clear vision while moving.

1.10. Motor output to the muscles and joints

A baby learns to balance through practice and repetition as impulses sent from the sensory receptors to the brain stem and then out to the muscles form a new pathway. With repetition, it becomes easier for these impulses to travel along that nerve pathway – a process called facilitation – and the baby is able to maintain balance during any activity. Strong evidence exists suggesting that such synaptic reorganization occurs throughout a person's lifetime of adjusting to changing motion environs.

This pathway facilitation is the reason dancers and athletes practice so arduously. Even very complex movements become nearly automatic over a period of time. This also means that if a problem with one sensory information input were to develop, the process of facilitation can help the balance system reset and adapt to achieve a sense of balance again.

For example, when a person is turning cartwheels in a park, impulses transmitted from the brain stem inform the cerebral cortex that this particular activity is appropriately accompanied by the sight of the park whirling in circles. With more practice, the brain learns to interpret a whirling visual field as normal during this type of body rotation. Alternatively, dancers learn that in order to maintain balance while performing a series of pirouettes, they must keep their eyes fixed on one spot in the distance as long as possible while rotating their body.

1.11. Motor output to the eyes

The vestibular system sends motor control signals via the nervous system to the muscles of the eyes with an automatic function called the vestibulo-ocular reflex (VOR). When the head is not moving, the number of impulses from the vestibular organs on the right side is equal to the number of impulses coming from the left side. When the head turns toward the right, the number of impulses from the right ear increases and the number from the left ear decreases. The difference in impulses sent from each side controls eye movements and stabilizes the gaze during active head movements (e.g., while running or watching a hockey game) and passive head movements (e.g., while sitting in a car that is accelerating or decelerating).

1.12. The coordinated balance system

The human balance system involves a complex set of sensorimotor-control systems. Its interlacing feedback mechanisms can be disrupted by damage to one or more components through injury, disease, or the aging process. Impaired balance can be accompanied by other symptoms such as dizziness, vertigo, vision problems, nausea, fatigue, and concentration difficulties.

The complexity of the human balance system creates challenges in diagnosing and treating the underlying cause of imbalance. The crucial integration of information obtained through the vestibular, visual, and proprioceptive systems means that disorders affecting an individual system can markedly disrupt a person's normal sense of balance. Vestibular dysfunction as a cause of imbalance offers a particularly intricate challenge because of the vestibular system's interaction with cognitive functioning, and the degree of influence it has on the control of eye movements and posture.

2. Assessment protocols

2.1. modified Clinical Test of Sensory Interaction on Balance - mCTSIB

Use the mCTSIB to quantify postural sway velocity (Figure 4) during four sensory conditions:

1. Eyes open firm surface;
2. Eyes closed firm surface;
3. Eyes open unstable surface (foam);
4. Eyes closed unstable surface (foam).

Each condition has three trials of 10 seconds.

The mCTSIB is designed to help the clinician assess the need for further testing in patients with complaints related to balance dysfunction, and to establish objective baselines for treatment planning and outcome measurement. The mCTSIB cannot provide impairment information specific to individual sensory, balance, or motor systems.

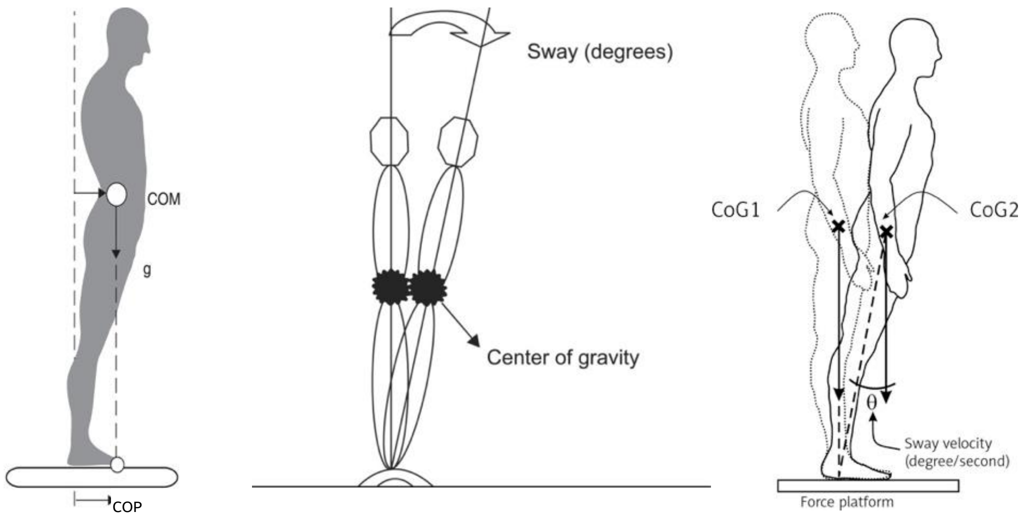


Figure 4 – Simplified illustrations of the center of pressure, sway angle and sway velocity (°/s).

At the end of performing all the conditions of the protocol it is possible to save the following balance data and generate a clinical report (Figure 5).

Data	Description
Trial time	Elapsed time: 10 seconds. In the case of loss of balance, appears the time until the fall has occurred
Sway velocity	Distance travelled by the center of pressure divided by the test time (°/s). If a fall occurs the value is 6 °/s
Mean sway velocity	Mean sway velocity for each condition
Composite sway velocity	Mean sway velocity for all 12 trials
COP alignment	Patient's initial COP position relative to the base of support center at the beginning of each test, expressed as a percentage of the Limit of Stability (LOS) and degrees

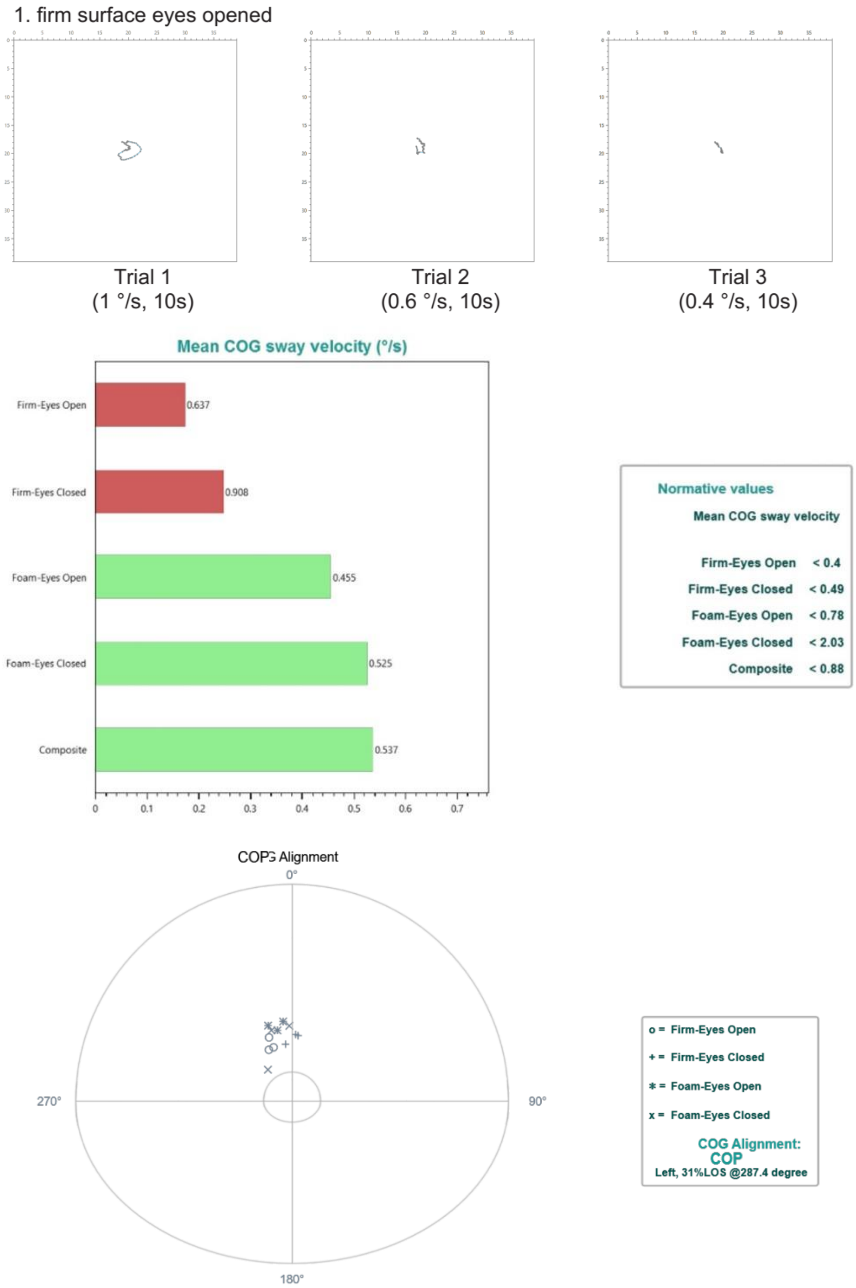


Figure 5 – Example of the results section of the mCTSIB clinical report.

Normal Response (indicated by green): The four conditions of the mCTSIB are designed to simulate conditions frequently encountered in daily life activities. Normal individuals maintain their COG near the center of the support base and minimize their sway regardless of the sensory challenge or condition.

Abnormal Response (indicated by red): For most patients with disequilibrium (with or without established etiology), the mCTSIB will document the presence of a balance problem and provide the information required to support further assessments. It also provides focus for the rehabilitation plan.

Clinical Significance: The mCTSIB can also be used, to a limited extent, to document progress in a rehabilitation program. Although the results of the mCTSIB can be used to distinguish normal balance performance versus abnormal balance performance, it cannot be used to discern the specific patterns of dysfunction. The combination of the mCTSIB and

LOS forms an objective screening tool for balance problems that can differentiate those patients who will benefit from a course of rehabilitation from those who require further diagnostic testing and more advanced balance rehabilitation.

2.2. Limits of Stability - LOS

The LOS protocol quantifies impairments in ability to intentionally displace the COG to the patient's stability limits without losing balance. The patient performs the task while viewing a real-time display of their COP position in relation to targets placed at the center of the base of support and at the stability limits (Figure 6). For each of eight directions, the test measures movement reaction time, movement velocity, movement distance, and movement directional control. For each of eight trials, the patient, on command, moves the COP cursor as quickly and accurately as possible towards a second target located on the LOS perimeter, set at 100% of the theoretical limits of stability, and then holds a position as close to the target as possible. The patient is allowed up to 8 seconds to complete each trial.

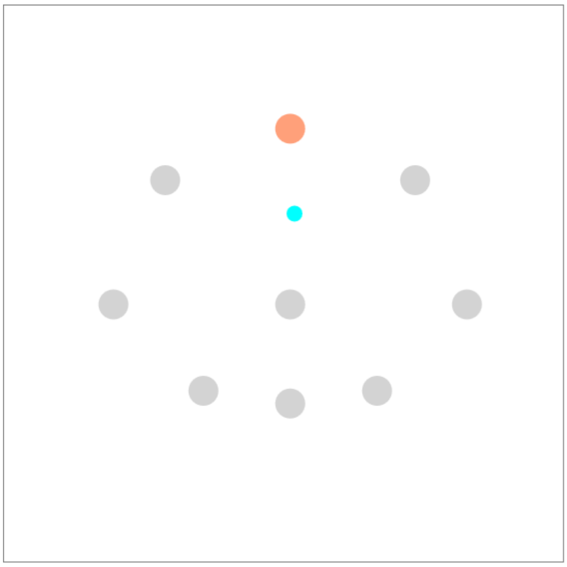


Figure 6 – Interface of LOS protocol.

This protocol is appropriate for:

- Older adults with mobility impairments;
- Athletes interested in rapid 'off the block' reactions and direction changes;
- Patients with peripheral neuropathic disorders: diabetes, polyneuropathy;
- Patients with central nervous system pathologies:
    - Degenerative diseases: Parkinson's disease, multiple sclerosis;
    - Acquired paralysis and paresis: stroke, brain injury.

The 8 directions of the protocol are: front, front/right, right, back/right, back, back/left, left and front/left. The distances of the limits of stability are calculated according to the height of the patient's center of gravity. These distances are calculated for 100% LOS, i.e. 8° left, right and front, and 4.5° back (see Figure 7).

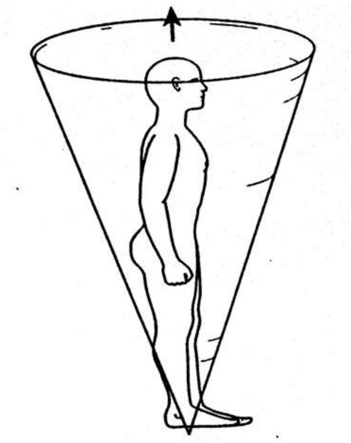


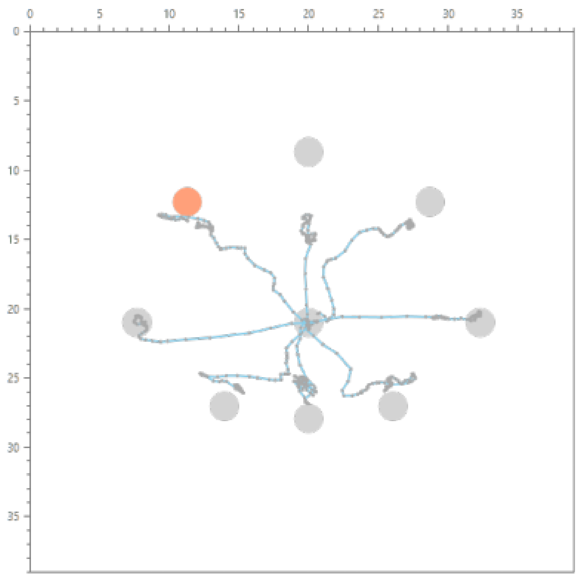
Figure 7 – Theoretical boundaries of the limits of stability.

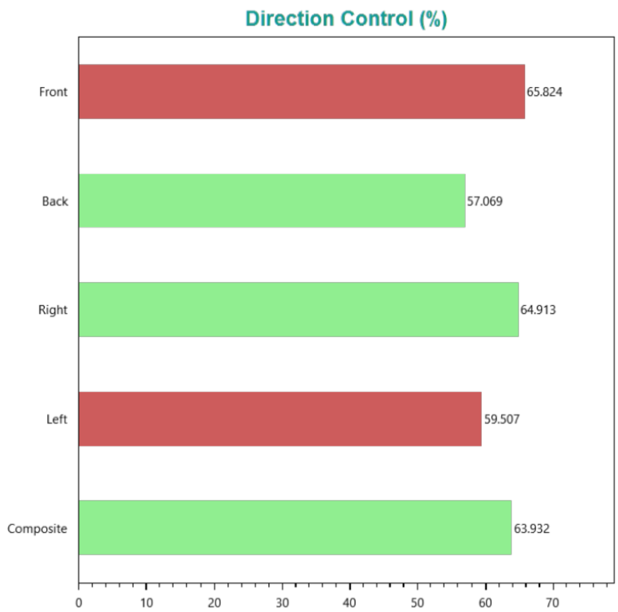
At the end of the protocol appears the trace of the pressure center and the following data can be saved and exported as a clinical report (Figure 8):

Data	**Description**
Reaction time	Time between the indication to move (2 seconds after clicking the Start button Time the color of the point changes) and the first movement of the patient, in seconds
Mean reaction time per cartesian axis	Mean reaction time per cartesian axis (front, right, back and left)
Movement velocity	Distance traveled by the center of pressure, between 5% and 95% of the first attempt, divided by 8 seconds (°/s).
Mean movement velocity per cartesian axis	Mean movement velocity per cartesian axis
Endpoint excursion	Distance from the first attempt to reach the orange dot, expressed as a percentage of LOS. The end of the first attempt is considered the point at which the initial movement towards the goal ceases
Endpoint excursion per cartesian axis	Mean endpoint excursion per cartesian axis
Maximum excursion	Maximum distance reached during 8 seconds, expressed as a percentage of LOS
Maximum excursion per cartesian axis	Mean maximum excursion per cartesian axis
Directional control	Percentage of movement in the intended direction minus off-axis movement during the first attempt
Directional control per cartesian axis	Mean directional control per cartesian axis

Results for each direction:

Direction	Front	Right / Forward	Right	Right / Backwards	Back	Left / Backwards	Left	Left / Forward
Reaction Time (s)	0.66	0.38	0.38	0.52	0.61	0.04	0.52	0.7
Movement Vel. (º/s)	3.9	3.2	5.5	4.1	3.3	3.2	6.2	3.1
Endpoint Exc. (%)	58	37	78	74	80	100	87	67
Maximum Exc. (%)	63	86	100	109	84	109	102	108
Dir. Control (%)	101	79	86	70	83	71	87	84





Normative values

	Dir. Control (%)
Front	> 69.51
Back	> 12.58
Right	> 61.45
Left	> 63.85
Composite	> 57.7

Figure 8 – Example of the results section for the LOS clinical report.

Normal Response (indicated by green): Performance within age-matched normative range is indicative of good voluntary motor control and adequate lower extremity proprioception, range of motion, and strength for mobility.

Abnormal Response (indicated by red): Abnormal performance is representative of a voluntary motor impairment. This can be a result of factors including:

- Biomechanics (range, strength);
- Sensory awareness;
- Central movement disorders;
- Perception (fear).

Clinical Significance: Provides information regarding voluntary motor control for safe and independent function in all activities of daily living (ADLs).

Ability to voluntarily move the COG to positions within the LOS is fundamental to mobility tasks such as reaching for objects, transitioning from a seated to standing position (or standing to seated), and walking.

Reaction time delays are commonly associated with difficulties in cognitive processing and/or motor diseases. Reduced movement velocities are indicative of high level central nervous system deficits such as Parkinson's disease and age-related disorders. Inability to reach targets in single movements, such as reduced endpoint excursions or excessively larger maximum excursions and poor directional control are indicators of motor control abnormalities. Excursions may be restricted by biomechanical limitations. Dizzy and/or unsteady patients and those fearful of falling may artificially restrict their excursions, while the strength of those with lower extremity weakness may be insufficient to attain and/or maintain stable target positions.

Limitations in the LOS may correlate to risk for fall or instability during weight shifting activities such as leaning forward to take objects from a shelf, leaning back for hair washing in the shower, or opening the refrigerator door. Patients with reduced stability limits in the AP direction tend to take smaller steps during gait, while laterally reduced limits can lead to broad-based gaits.

2.3. Rhythmic Weight Shift - RWS

Use the Rhythmic Weight Shift protocol to evaluate the transfer capacity of the center of pressure rhythmically in the sagittal and anteroposterior plane, at three different velocities: slow (3s), moderate (2s) and fast (1s). This protocol measures the velocity in the axis and the movement control between two targets at 50% of patient's LOS (Figure 9).

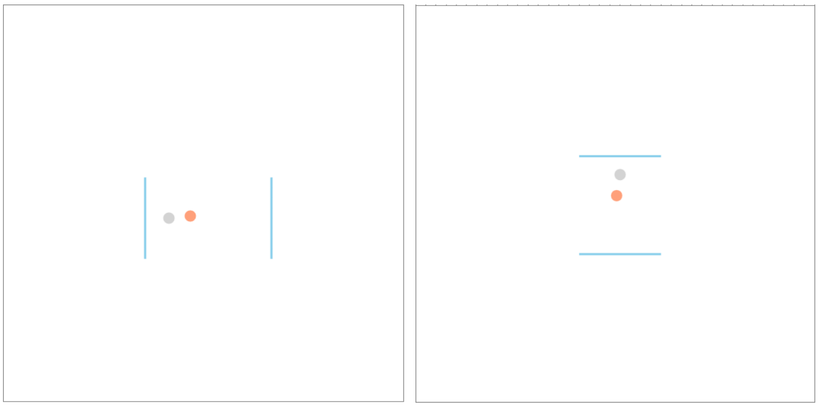


Figure 9 - Interface of RWS protocol for the two planes: sagittal and anteroposterior.

During performance of each task, the patient views a real time display of their COP position relative to a target moving (gray ball) at the desired pace and amplitude. The patient has to reach the gray ball, which is in motion, and control the load transfer at same pace as the gray point. The patient must change direction when reaching the blue line, at the same time of the beep signal. For each direction and pace, the RWS measures movement velocity and directional control.

Appropriate for patients with:

- Central Nervous System Pathologies:
  - Degenerative diseases: Parkinson's disease, multiple sclerosis;
  - Acquired paralysis and paresis: stroke, brain injury;
- Peripheral Neuropathic Disorders:
  - Diabetes, polyneuropathy;
- Inability to perform the LOS even after instruction and attempt. The RWS then becomes the voluntary movement test of choice.

At the end of the protocol the pressure center trace for each of the tests, in the sagittal and anteroposterior directions, at the three speeds mentioned appears (Figure 10). These images also appear in the clinical report, such as the following data (Figure 11):

Data	**Description**
On-axis velocity	COP movement velocity along the specified direction (°/s)
Composite on-axis velocity	Mean velocity at the three speeds
Directional control	Percentage of movement in the desired direction minus off-axis movement
Composite directional control	Mean directional control at the three speeds

The normative values for each variable are presented next to the results.

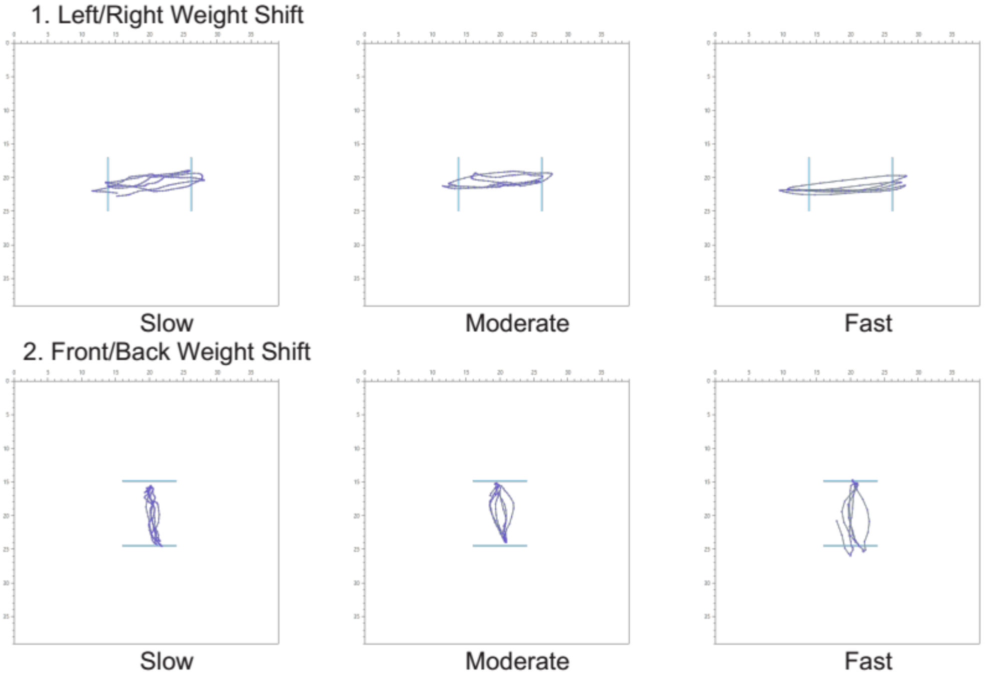


Figure 10 – Example of the trace of the COP for the two directions at the three speeds tested.

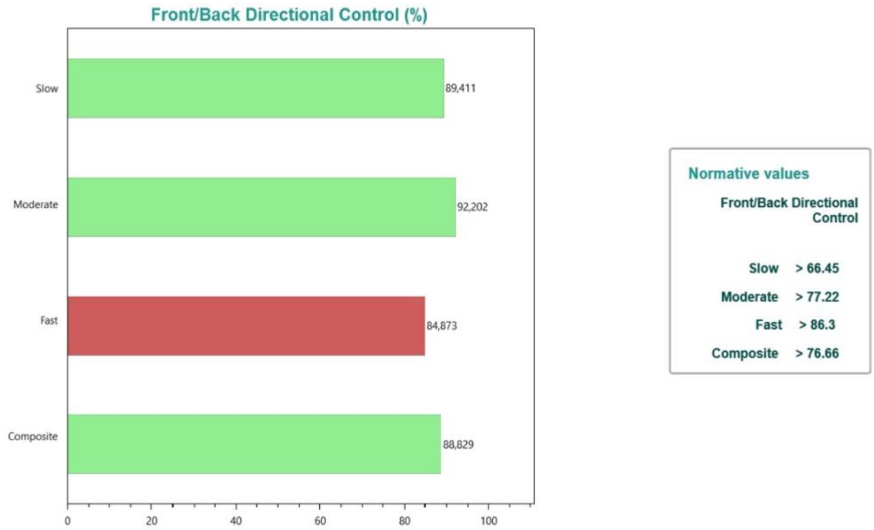


Figure 11 – Example of the results section for the RWS clinical report.

Normal Response (indicated by green): Subjects attain the required average velocities set by the pacing target and cover the full distance between the specified movement boundaries (50% LOS) with good directional control.

Abnormal Response (indicated by red): Patients with motor disorders disrupting normal timing of movement control may exhibit slower than normal movement velocities, poor directional control, or a combination of these two problems.

Clinical Significance: Provides information regarding a patient's effective timing of motor control for basic safety in performance of activities of daily living (ADLs) and gait weight transfer.

Normal individuals attain the required average velocities by maintaining the rhythm set by the pacing target and by covering the full distance between the specified movement boundaries. At the same time, their movements are straight and well coordinated, with motions in the off-axis direction being a small percentage of the on-axis motion. Functional consequences include an inability to meet the timing demands of the environment, such as crossing the street and stepping onto elevators/escalators. Instability may result when performing activities that require rapid movement speeds, variability in speeds, or changing directions. Rhythmic, reciprocal movement patterns are required in many high level athletic and leisure interests.

2.4. Weight Bearing/Squat - WBS

The WBS protocol quantifies the patient’s ability to perform squats with the knees flexed at 30°, 60°, and 90°, while maintaining equal weight on the two legs (Figure 12). In the erect position, most body weight is borne through the skeletal system, and relatively less stress is placed on the knee and hip joints. Increasing depths of squat place greater stress on the knees and hips, making these positions more sensitive in detecting weight-bearing abnormalities related to lower extremity musculoskeletal injuries.

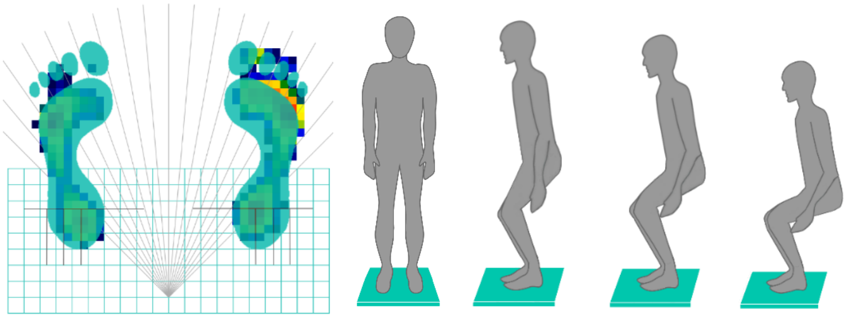


Figure 12 - Interface of WBS protocol with the various angles of knee flexion: 0º, 30º, 60º and 90º.

This protocol allows observation of weight distribution in the sagittal plane with the patient standing up with different knee flexion angles.

At the end, a graph with the percentage of body weight of the patient on each side (left and right) with knees straight (at 0°) and with knees bent at 30°, 60° and 90° appears. It is also possible to save this data and generate a clinical report (Figure 13).

Data	Description
Percentage of body weight	Percentage of weight on each side of the sagittal plane, for each angle of knee flexion

Figure 13 – Example of the results section for the WBS clinical report.

Normal Response (indicated by green): Normal individuals maintain body weight within ±7% of equal on the two legs over the full range of squatting positions.

Abnormal Response (indicated by red): Reduced weight bearing on one leg may reflect sensory (proprioceptive) or strength loss, reduced range of motion, and/or pain. Bending, stooping and squatting positions substantially increase stress on the ankles and knees, and may identify weight-bearing differences not detectable in a less challenging (fully erect) position.

Clinical Significance: Provides information regarding the symmetry of the patient's voluntary motor control for basic safety in performance of activities of daily living (ADLs), sports or leisure activities.

Patients with lower extremity orthopedic injuries may exhibit equal weight bearing in the erect position, but will bear a preponderance of weight on the uninvolved side during more stressful squatting positions. Patients with generalized or unilateral weaknesses will demonstrate impaired motor control for sit-to-stand transitions or an inability to safely retrieve objects from the floor. In the athletic population, impairments may result in reduced readiness to move side-to-side or accuracy of weight shift or thrust during squat-to-extend movements.

2.5. Unilateral Stance - US

The US assessment quantifies the patient’s ability to maintain postural stability while standing on one leg at a time with the eyes open and closed (Figure 14). The US enhances the observational testing of single leg stance performance by providing an objective measure of patient sway velocity for each of the four task conditions. The length of each trial is ten seconds.

The US is highly sensitive, but not specific because a large number of independent factors can impact performance. A partial list of these factors includes lower extremity strength and weight bearing control, sensory balance control, movement strategies, and prior practice with the task.

Use this protocol to measure the balance in four conditions: left foot lifted up with eyes open, left foot lifted up with eyes closed, right foot lifted up with eyes open and right foot lifted up with eyes closed. This protocol also allows to evaluate the difference of oscillation (in percentage) between the left and right side with the eyes opened and closed.

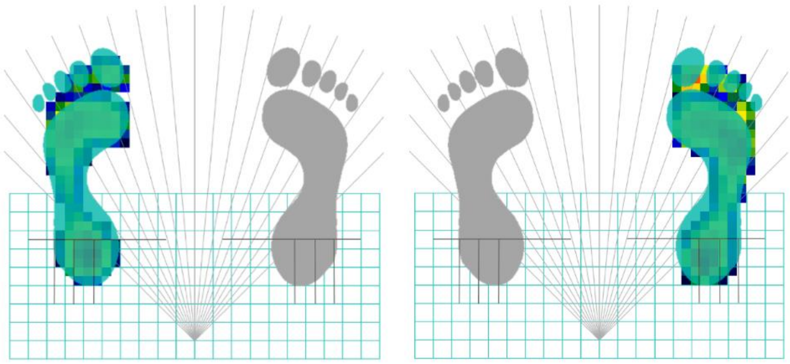


Figure 14 - Interface of US protocol, for left and right foot, respectively.

At the end, the following results are presented for each of the indicated conditions, in the form of graphs (Figure 15).

Data	Description
Trial time	Elapsed time: 10 seconds. In the case of loss of equilibrium, appears the time until the fall has occurred
Sway velocity	Distance traveled by the center of pressure divided by the test time (°/s). If a fall occurs the value is 6 °/s
Mean sway velocity	Mean sway velocity for each condition
Sway velocity difference	Sway velocity difference (in percentage) between left and right side with eyes open and closed. The bar points to the side with better performance

In the clinical report can be observed the pressure center trace for each test, as well as the graphs with the aforementioned data. The normative values for each variable are presented below the results.

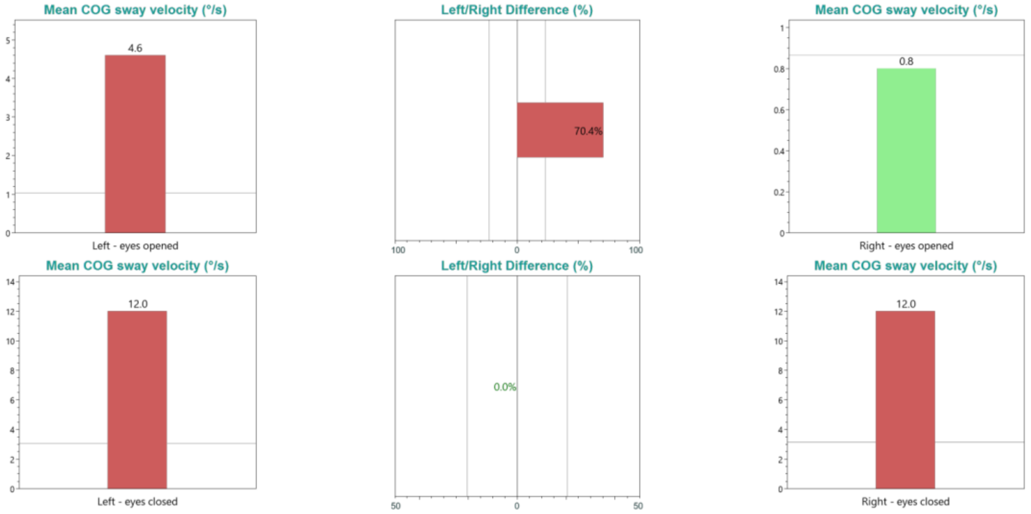


Figure 15 – Example of the results for the US protocol.

Normal individuals have significantly more sway standing on one foot versus two, and even more sway on one foot with eyes closed. Patients who become unstable may have difficulty using visual or somatosensory information for balance control, and/or may have musculoskeletal problems that make it difficult to compensate. Functional consequences are significant for performance of activities that require single-leg balance, such as donning pants or hosiery, ascending or descending elevations, or navigating narrow support surfaces, such as ladders and scaffolding.

2.6. Fall Risk - FR

Falls are a common occurrence among older people, even for those in good health and with no apparent balance problems. Fall Risk test allows identification of potential fall candidates. Test results are compared to age-dependent normative data. Scores higher than normative values suggest further assessment for lower extremity strength, proprioception, and vestibular or visual deficiencies. The quantification of the patient's postural sway velocity can be used to predict risk. Velocity can be described as the speed of an individual's sway as balance is maintained. Higher velocities, when cues are given to specifically stand as motionless as possible, are suggestive of postural control deficits. The Fall Risk test protocol

(Figure 16) is based on research from the University of Dayton (Bigelow KE and Berme N. 2011. 'Development of a protocol for improving the clinical utility of posturography as a fall-risk screening tool' J Gerontol A Biol Sci Med Sci 66A: 228–233) and the University of Jyväskylä in Finland (Pajala, S. *et al.* 2008. 'Force platform balance measures as predictors of indoor and outdoor falls in community-dwelling women aged 63-76 years' J Gerontol A Biol Sci Med Sci 63A:171–178).

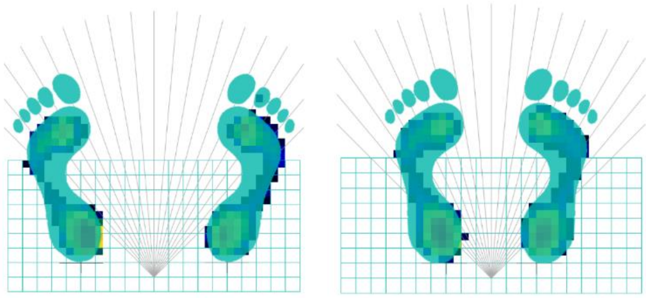


Figure 16 - Interface of Fall Risk protocol, for comfortable and narrow stance.

Use this protocol to measures the static balance in four conditions:

1. Comfortable stance with eyes open;
2. Comfortable stance with eyes closed;
3. Narrow stance with eyes open;
4. Narrow stance with eyes closed.

After performing all the conditions of the protocol, the value of the sway velocity index for each of the conditions appears. This sequence of tests can provide a fall risk prediction.

At the end of the protocol, it is possible to save the following data and generate a clinical report.

Data	**Description**
Velocity	Distance traveled in the sagittal plane divided by the test time, 45 seconds (mm/s)
Composite velocity	Mean velocity for all conditions
Sway velocity index (SVI)	Value based on the velocity and height of the patient, normalized by the natural logarithm function
Composite SVI	Mean SVI for all conditions
Z-Score	Number of standard deviations of the SVI from the mean value indicated in the normative values
Composite Z-Score	Mean Z-Score for all conditions

In the clinical report (Figure 17) can be observed the pressure center trace for each condition. The normative values for each condition are presented next to the results. The color of the bar will be green, yellow or red depending on the result, higher values will be red (meaning less stable) and lower values than normative values will be green.

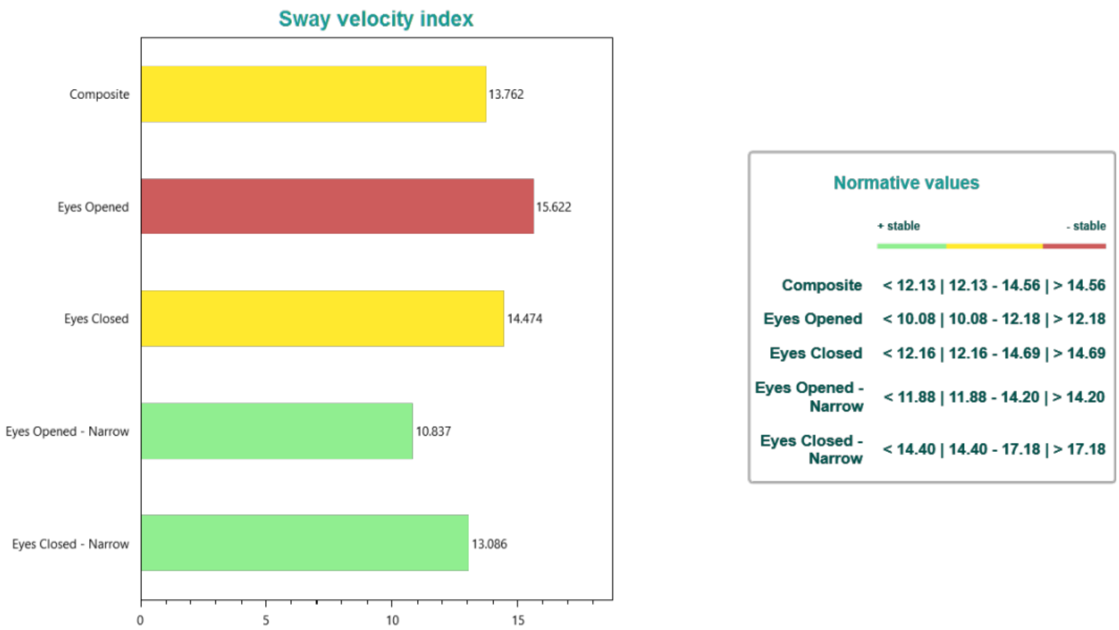


Figure 17 – Example of the results section for the FR clinical report.

3. Balance assessment and training applications

PhysioSensing is indicated to assist physiotherapy activities, physical and vestibular rehabilitation and neurorehabilitation, especially in the early rehabilitation of stroke and neuromusculoskeletal conditions associated to lower limbs and gait rehabilitation. More concrete applications provided by medical devices with visual evaluation biofeedback and balance training are documented by the scientific community:

Neurological	• Stroke or Cerebrovascular Accident (CVA) Patients • Parkinson Disease • Amyotrophic Lateral Sclerosis (ALS/ Lou Gehrig's Disease) • Multiple Sclerosis • Spinal Cord or Head Trauma - Any head or spinal cord injury resulting in loss of balance or ambulatory motor skills. • Rehabilitation with these patients involves: - Restoration of effected motor skills by retraining new neural pathways. - Restoration of kinesthetic sense for proper body positioning to maintain balance and weight transfer for ambulation. • PhysioSensing is effective because: - The instant biofeedback makes it easy for the patient to relate to and repeat the motions. - Safe controlled environment that allows the patient to progress from non weight bearing to weight bearing. - Objectives and reproducible so that progress can be monitored as well as rehab sessions documented.
Orthopaedics	Lower Extremity Patients: - ACL's - Total Knee - Total Hip - Ankle Sprain - Fractures - Amputees - weight bearing and balance with the prosthesis - High Tibial Osteotomies - Risk for Fall
	Spine Patients: - Ankle, knee and hip movement strategies for improving posture and mechanics. - Core Stabilization using a gym ball on PhysioSensing.
	Upper Extremity Patients: - Scapular stabilization drills, where the patient uses his arms to load on platform
	Geriatric Patients (both neurological and orthopedic): - Balance and weight shift training as part of rehabilitation from a total hip or knee replacement, or a stroke. - Kinesthetic Balance Training. - Weight bearing.
Sports Medicine	These patients can work the way either non weight bearing, or full weight bearing. They can work on weight shifting, proprioceptive and stabilization drills with or without perturbation (with or without foam). Also, some clinicians are using this type of device for high level agilities.
Vestibular Disorders	Patients with balance disorder can feel unsteady or dizzy. Either if they are standing, sitting, or lying down, they might feel as if they are moving, spinning, or floating. When walking, they might suddenly feel as if they are tipping over. Everyone has a dizzy spell now and then, but the term "dizziness" can mean different things to different people. For one person, dizziness might mean a fleeting feeling of faintness, while for another it could be an intense sensation of spinning (vertigo) that lasts a long time. The symptoms of a balance disorder might include: • Dizziness or vertigo (a spinning sensation). • Falling or feeling as if they are going to fall. • Staggering when they try to walk. • Lightheadedness, faintness, or a floating sensation. • Blurred vision. • Confusion or disorientation. Other symptoms might include nausea and vomiting; diarrhea; changes in heart rate and blood pressure; and fear, anxiety, or panic. Symptoms may come and go over short time periods or last for a long time and can lead to fatigue and depression. PhysioSensing can be used to evaluate those conditions.

4. Scientific Evidence

Topic	Subjects	Title	Authors	Cita-tions	Publication	Key-evidences
Modified Clinical Test of Sensory Interaction on Balance	Multiple Sclerosis	Use of Awareness Through Movement Improves Balance and Balance Confidence in People with Multiple Sclerosis: A Randomized Controlled Study	Stephens, James; DuShuttle, Dominique; Hatcher, Carla; Shmunes, Jenifer; Slaninka, Christine	55	Journal of neurologic physical therapy 2001 25(2)	The ATM (Awareness Through Movement) group exhibited significantly improved mCTSIB scores indicating an average center of pressure position closer to theoretical center, had significantly fewer abnormal mCTSIB tests, and demonstrated improved balance confidence compared to controls. There was a trend toward improvement in all other measures in the ATM group compared to controls.
	Benign paroxysmal positional vertigo	Modified clinical test of sensory interaction on balance test use for assessing effectiveness of Epley maneuver in benign paroxysmal positional vertigo patients' rehabilitation	Yones Lotfi , Mohanna Javanbakht , Maryam Sayaf , Enayatollah Bakhshi	0	Aud Vest Res (2018);27(1):12-18.	Meanwhile, it seems that in addition to considering the time criterion of maintaining the balance in the mCTSIB test, the use of the amount of sway, especially in patients with BPPV, also provides more complete information for the specialists in the field of balance in order to estimate the individual balance problems and the effectiveness of therapeutic maneuvering. mCTSIB is seems be a valid test with simple and quick apply for verifying the effectiveness of Epley maneuver in BPPV patients.
	Attention Deficit Hyperactivity Disorder Children	Objective Measurement of the Balance Dysfunction in Attention Deficit Hyperactivity Disorder Children	Yufeng Zang, Bomei Gu, Qiujin Qian, Yufeng Wang	46	Chinese Journal of Clinical Rehabilitation, May 2002, Vol. 6, No. 9	We found that the sway velocity of center of gravity on conditions, firm surface with eyes closed, foam pad with eyes open and foam pad with eyes closed, was significantly higher ($P < 0.03$) in ADHD group than in controls. We concluded that the sensory inputs, the sensory integration, and/or the inhibition of excessive movement are impaired in ADHD children, which result in the balance dysfunction. mCTSIB can provide more accurate evaluation on rehabilitation therapy. Combining CSIS and other methods, e.g., neuroimaging, could further uncover the mechanisms of inhibition disability of this group.

Limits of Stability	Elderly at different risk of fall	Effect of a group-based exercise program on balance in elderly	Tatjana Bulat, Stephanie Hart-Hughes, Shahbaz Ahmed, Pat Quigley, Polly Palacios, Dennis C Werner, and Philip Foulis	72	Clin Interv Aging. 2007 Dec; 2(4): 655–660	We found statistically significant improvement in balance outcomes as a result of an 8 week group functional balance training class. LOS composite Reaction Time (RT) and composite movement velocity (MVL) showed trends toward improvement while LOS composite end point excursion (EPE), maximum excursion (MXE) and directional control (DCL) all were significantly improved when compared to baseline. An eight week group functional balance training class was safe and effective in improving balance outcomes in a cohort of elderly veterans at risk for falls.
	Multiple Sclerosis	The Role of Clinical and Instrumented Outcome Measures in Balance Control of Individuals with Multiple Sclerosis	Neeta Kanekar and Alexander S. Aruin	19	Multiple Sclerosis International 2 013;2013:1901 62	Both, the distance of the frst movement towards the target (EPE) and the maximum distance reached (MXE) by the MS group, were signifcantly smaller than the distance reached by the HC group. Posthoc test demonstrated that for each direction, the MS group had smaller MXE than the HC group. Specifcally, the MXE for the MS group towards the right side was smaller as compared to the MXE for the HC group towards the right side (*P* = 0.037) and towards the lef side (*P* = 0.038). Moreover, irrespective of the direction, the MS group had smaller MXE than the HC group (*P* = 0.012). Implementation of both clinical and instrumented tests of balance is important for the planning and evaluation of treatment outcomes in balance rehabilitation of people with MS.
Rhythmic Weight Shift	Vestibular Patients	Posturografía estática con pruebas dinámicas. Utilidad de los parámetros biomecánicos en la valoración del paciente vestibular (Static Posturography With Dynamic Tests. Usefulness of Biomechanical Parameters in Assessing Vestibular Patients)	Ramón Balaguer García, Salvador Pitarch Corresa, José María Baydal Bertomeu, María M. Morales Suárez-Varela	10	Acta Otorrinolaringo l Esp. 2012;63:332-338	In some patients, posturography can detect the negative influence exerted by a vestibular alteration on postural stability. It does not replace the classic tests which evaluate the vestibulo-ocular reflex, but instead provides complementary information, enabling a better understanding of the functional status of patients with instability. With the exception of the displacement angle, all biomechanical parameters of static posturography were able to discriminate between normal and pathological subjects in our sample. The RWS test proved useful to discriminate between normal and pathological subjects in our population. Therefore, vestibular disorders may be able to significantly alter the voluntary control of rhythmic movement whilst standing.

	Hemiplegic stroke patients	Effects of balance training on hemiplegic stroke patients	Chen IC, Cheng PT, Chen CL, Chen SC, Chung CY, Yeh TH	111	Chang Gung Med J. 2002 Sep;25(9):583-90	For dynamic function training, the patients were instructed to practice controlling their weight shifts by tracing the moving targets on the screen in every main direction while the condition of LOS set at 50%. We found dynamic balance function showed significant improvements in patient with visual feedback training when compared with those receiving conventional therapy only. Patients in the trained group also showed significant improvements in the self-care ability at 6 months of follow up.
Weight Bearing Squat	Individuals with Mental Retardation	Effects of Balance Training on Individuals with Mental Retardation	Karen M. Smail and Michael Horvat	9	Clinical Kinesiology: Journal of the American Kinesiotherapy Association 2005	It is interesting to note that after training, symmetry across left and right sides for weight distribution (51.9% right and 48.1% left) was apparent. This demonstrates that individuals with mental retardation will respond to balance training interventions and supports the development of specific programs that foster balance related skills. This study suggests that symmetrical weight distribution can be corrected with proper training thus resulting in more efficient movement patterns
	Stroke	Impact of Yoga on Postural Stability in Stroke	Peter Altenburger A , Arlene Schmid A , Marieke Van Puymbroeck and Kristine Miller K	3	Int J Neurorehabilitation 2016, 3:1	Postural orientation was measured using the weight bearing squat assessment. Prior to participation in yoga, significant weight distribution asymmetry was observed during full upright standing. Subjects demonstrated greater than 50% improvement in symmetry alignment for different standing positions.
Unilateral Stance	Peripheral Neuropathy	Unipedal Stance Testing in the Assessment of Peripheral Neuropathy	Edward A. Hurvitz, James K. Richardson, Robert A. Werner	45	Arch Phys Med Rehabil. 2001 Feb;82(2):198-204.	Abnormal unipedal stance time (< 45s) identified peripheral neuropathy with a sensitivity of 83% and a specificity of 71%, whereas a normal unipedal stance time had a negative predictive value of 90%. Abnormal unipedal stance time was associated with an increased risk of having peripheral neuropathy on univariate analysis. Our results suggest that unipedal stance testing is useful in detecting peripheral neuropathy.
	Lumbar discectomy patients with and without pain	Comparison of postural control in unilateral stance between healthy controls and lumbar discectomy patients with and without pain	Katie Bouche Veerle Stevens Dirk Cambier Jacques Caemaert Lieven Danneels	36	Eur Spine J. 2006 Apr; 15(4): 423–432.	In lumbar discectomy patients, postural sway in unilateral stance is influenced by age, the presence of pain and the side of former disc herniation. Long-term following lumbar discectomy, there is no complete recovery of postural control. In the eyes open condition, balance of patients with pain was significantly worse than in controls (P=0.003). In the eyes closed condition, the sway in both groups of lumbar discectomy patients was significantly worse than in controls (pain-free P=0.009/painful P<0.001). in stance on the leg of the non-operated side, postural sway was significantly lower in the eyes open condition compared to the eyes closed condition.

Fall Risk	Elderly	Postural stability in the elderly: a comparison between fallers and non-fallers	I. MELZER, N. BENJUYA, J. KAPLANSKI	474	Age Ageing. 2004 Nov;33(6):602-7.	Fallers had significantly higher COP path length, COP velocity and ML sway in the eyes open condition, compared with non-fallers (21.6%, 26.3% and 27.5%, respectively). When standing on foam, fallers had significantly higher elliptical area and ML sway compared with non-fallers (14.1% and 28.5%, respectively). With eyes closed, fallers had a significantly higher COP path length, COP velocity, elliptical and ML sway (25%, 27%, 34.8% and 30%, respectively). Multiple regression analysis revealed that those who had a higher ML sway had a three times higher risk of falling. In conclusion, there is evidence that simple, safe forceplate measurement of spontaneous postural sway can identify elderly individuals at risk of falls and can permit a possible application as a preliminary screening tool for the risk of falling.
	Older adults	Development of a Protocol for Improving the Clinical Utility of Posturography as a Fall-Risk Screening Tool	Bigelow KE, Berme N.	42	J Gerontol A Biol Sci Med Sci. 2011 Feb;66(2):228-33	It was found that the eyes closed comfortable stance testing condition and its associated model best differentiated recurrent fallers from nonrecurrent fallers. The current work suggests that a more comprehensive approach to analyzing COP data where traditional, fractal, and even demographic information are considered jointly may be more insightful in differentiating recurrent fallers from nonrecurrent fallers than examining only a single or few selected measures.
	Older woman	Force Platform Balance Measures as Predictors of Indoor and Outdoor Falls in CommunityDwelling Women Aged 63-76 Years	Pajala S, Era P, Koskenvuo M, Kaprio J, Törmäkangas T, Rantanen T.	184	J Gerontol A Biol Sci Med Sci. 2008 Feb;63(2):171-8.	The participants in the highest COP movement tertile, irrespective of the balance test, had a two- to fourfold risk for indoor falls compared to participants in the lowest COP tertile of the test. Thus, our study accumulates evidence for the relationship between indoor falls and intrinsic risk factors and shows that the force platform method serves as a sufficiently sensitive balance measure to identify older persons who are susceptible to falls due to intrinsic risk factors.
Biofeedback visual	Stroke	Biofeedback rehabilitation of posture and weightbearing distribution in stroke: a center of foot pressure analysis		17		The indices of postural stability, derived from CoP signal analysis, provided a meaningful approach for studying postural control recovery. The recovery of symmetrical weight-bearing distribution due to the audio-visual biofeedback approach was shown by the M-L mean CoP values that were reduced only in the SG (Study Group), at the end of the rehabilitation program, under both visual conditions.
	Elderly woman	Changes in Postural Balance in Frail Elderly Women during a 4-Week Visual Feedback Training: A Randomized Controlled Trial	Sihvonen S.E., Sipilä S. and Era P.A.	195	Gerontology 2004;50:87–95	Our study supports the notion that through enhanced use of visual feedback, the learning of balance skills can be facilitated. The participants of the EG (exercise group) showed an improved ability to move their center of pressure more quickly and accurately through the different tracks used in testing. The EG showed improvement after the training period in performance time and distance of all dynamic force platform balance tests.

Games	Older adults	Effects of an Interactive Computer Game Exercise Regimen on Balance Impairment in Frail Community-Dwelling Older Adults: A Randomized Controlled Trial	Tony Szturm, Aimee L. Betker, Zahra Moussavi, Ankur Desai, Valerie Goodman	120	Phys Ther. 2011 Oct;91(10):1449-62	Findings demonstrated significant improvements in posttreatment balance performance scores for both groups, and change scores were significantly greater in the experimental group compared with the control group. In summary, these findings demonstrated that graded, dynamic balance exercises on different surfaces could feasibly be coupled with video game tasks. This coupling, in turn, resulted in a greater improvement in dynamic standing balance control compared with the typical exercise program.
	Acquired brain injury	Effectiveness of a Wii balance board-based system (eBaViR) for balance rehabilitation: a pilot randomized clinical trial in patients with acquired brain injury	José-Antonio Gil-Gómez, Roberto Lloréns, Mariano Alcañiz and Carolina Colomer	328	Journal of NeuroEngineering and Rehabilitation2 0118:30	The clinical study presented in this paper suggests that virtual rehabilitation provided significant improvement in static balance compared to traditional treatment. atients using eBaViR had a significant improvement in static balance (p = 0.011 in Berg Balance Scale and p = 0.011 in Anterior Reaches Test). Regarding dynamic balance, the results showed significant improvement over time in all these measure. The results suggest that eBaViR represents a safe and effective alternative to traditional treatment to improve static balance in the ABI population.
	Lower limb power rehabilitation	Lower limb power rehabilitation (LLPR) using interactive video game for improvement of balance function in older people	Chen P.Y., Wei S.H., Hsieh W.L., Cheen J.R., Chen L.K. and Kao C.L.	41	Archives of Gerontology and Geriatrics 55 (2012) 677–682	For clinical assessments (balance, mobility, and selfconfidence), exercise group showed significantly better scores. The STS (sit-to-stand) movements in video-game-based training mimic real life situations which may help to transfer the training effects into daily activities. After six-weeks of training, the video-game-based exercise group displayed an improvement in lower limb muscle power, with a percentage change 64%.
	Older adults	Games-based biofeedback training and the attentional demands of balance in older adults	Heiden E. and Lajoie Y.	38	Aging Clinical and Experimental Research, 2010; Vol. 22, No. 5-6	Participants in the training group significantly decreased their reaction time from pre to post testing in a dual task paradigm compared to a control group. The training group also significantly increased their scores on the CB&M scale compared to control participants. Games based balance biofeedback training using a range of training postures can significantly improve functional balance in exercise trained older adults by reducing the attentional demands of postural control.
Neurological	Cerebral palsy	Computerized static posturographic assessment after treatment of equinus deformity in children with cerebral palsy	Bourelle S, Berge B, Gautheron V, Cottalorda J.	11	J Pediatr Orthop B. 2010 May;19(3):211-20	After treatment of the equinus deformity, the best improvements were observed for the mCTSIB with the eyes closed on the foam surface and for the dynamic tests demanding active tasks from the children, such as weight shifting. After treatment, mean weight-bearing asymmetry measured by the Weight Bearing Squat was significantly improved at 30º of knee flexion. The Balance Master offers the opportunity for an objective and easy assessment of postural control in children with cerebral palsy.

	Peripheral Neuropathy	Using Posturography to Detect Unsteadiness in 13 Patients With Peripheral Neuropathy: A Pilot Study	Reid VA, Adbulhadi H, Black KR, Kerrigan C, Cros D.	16	Neurol Clin Neurophysiol. 2002;2002(4): 2-8	Posturography showed abnormal sway patterns only in patients who had EMG abnormalities consistent with large- Žber peripheral neuropathy. These sway patterns differed signiŽcantly from those of the control subjects. Posturography may therefore be the test of choice for assessing functional deŽcits in patients with peripheral neuropathy—speciŽcally, the deŽcits that increase the risk of falling.
	Chronic tension-type headache	Impaired postural control in patients affected by tension-type headache	Giacomini PG, Alessandrini M, Evangelista M, Napolitano B, Lanciani R, Camaioni D.	31	Eur J Pain. 2004 Dec;8(6):579-83	Spectral analysis of body sway shows a significantly increased body sway at low and middle frequencies on the antero-posterior (y) plane and at low frequencies on the lateral (x) plane, in both open and closed eyes condition. We believe that, in clinical practice, posturographic results might help not only in the diagnosis of a postural disturbance, but even more in the follow-up of patients, revealing any change of the patient postural pattern during and after the medical and/or rehabilitative treatment.
	Parkinson's disease	Static posturography in aging and Parkinson's disease	Guntram W. Ickenstein, Helmut Ambach, Antonia Klöditz, Horst Koch, Stefan Isenmann, Heinz Reichmann, and Tjalf Ziemssen	30	Front Aging Neurosci. 2012; 4: 20	The platform Romberg-test with closed eyes detected significant differences in elderly people and patients with Parkinson's disease, which could be objectively quantified with static posturography testing. Therefore, we highly recommend the use of a standard platform measurement test in a geriatric setting. Especially the marked area and mean sway seem to be reliable parameters for monitoring balance in clinical practice.
	Neuro-ophthalmic deficits	Postural control after traumatic brain injury in patients with neuro-ophthalmic deficits	Agostini V, Chiaramello E, Bredariol C, Cavallini C, Knaflitz M.	7	Gait Posture. 2011 Jun;34(2):248-53	Using the proposed 10-trial protocol it was possible to clearly distinguish balance abnormalities of TBI patients with respect to controls. Moreover, we found that the severity of the residual neuro-ophthalmic deficit is correlated to the severity of the balance impairment. This is of paramount importance from a clinical perspective since it demonstrates that static posturography, associated to the presented protocol, can be applied to objectively evaluate the balance performances of a patient enrolled in a rehabilitation program and assess his/her progresses.

	Multiple sclerosis	Balance Rehabilitation Unit (BRUTM) posturography in relapsingremitting multiple sclerosis	Natália Kessler; Maurício Malavasi Ganança; Cristina Freitas Ganança; Fernando Freitas Ganança; Sabrina Chiogna Lopes; Ana Paula Serra; Heloisa Helena Caovilla	22	Arq Neuropsiquiatr 2011;69(3):485-490	Posturography was sensitive to identify abnormalities in the balance of patients with no obvious equilibrium disturbances. In conclusion, the evaluation of balance control with the posturography of the Balance Rehabilitation Unit (BRUTM) enables the identifcation of abnormalities of the sway velocity and confdence ellipse of the body's center of pressure distribution area in patients with relapsingremitting multiple sclerosis.
	Stroke	Post-stroke balance training: Role of force platform with visual feedback technique	Srivastava A., Taly A.B., Gupta A., Kumar S. and Murali T.	124	Journal of the Neurological Sciences 287 (2009) 89–93	This study shows that force platform with visual feedback technique is an effective approach for post-stroke balance training as it results in better locomotor abilities. The analysis revealed statistically significant differences for all primary and secondary outcome measures at follow-up.
	Stroke	The effects of balance training on gait late after stroke: a randomized controlled trial	Yavuzer G., Eser F., Karakus D., Karaoglan B. and Stam H.J.	201	Clinical Rehabilitation 2006; 20: 960-969	The difference between before-after change scores of the groups was significant for pelvic excursion in frontal plane (P=0.039) and vertical ground reaction force (P=0.030) in favour of experimental group. Balance training using force platform biofeedback in addition to a conventional inpatient stroke rehabilitation programme is beneficial in improving postural control and weight-bearing on the paretic side while walking late after stroke.
	Diabetic Neuropathy	The Forefoot-to-Rearfoot Plantar Pressure Ratio Is Increased in Severe Diabetic Neuropathy and Can Predict Foot Ulceration	Caselli A., Pham H., Giurini J.M., Armstrong D.G. and Veves A.	254	Diabetes Care. 2002 Jun;25(6):1066-71.	The data suggest that both forefoot and rearfoot peak plantar pressures are increased in diabetic patients with peripheral neuropathy, but the F/R peak plantar pressure ratio was significantly higher only in patients with severe neuropathy, indicating an imbalance in pressure distribution with increasing degrees of neuropathy.
Orthopedics	Osteoarthritis	Balance Control and Knee Osteoarthritis Severity	Hee-Sang Kim, Dong Hwan Yun, Seung Don Yoo, Dong Hwan Kim, Yong Seol Jeong, Jee-Sang Yun, Dae Gyu Hwang, Pil Kyo Jung, and Seong He Choi.	55	Ann Rehabil Med. 2011 Oct; 35(5): 701–709	Patients with moderate to severe osteoarthritis (AO) exhibited signifcantly higher stability indices in all positions than patients with mild OA. The Fourier index was also higher in patients with moderate to severe OA than in patients with mild OA. We observed that moderate to severe OA patients had diminished balance control compared to mild OA patients and we were able to deduce that a decrease in muscle strength, proprioception, and increased pain contributes to postural instability. Quantitative evaluation using force plates with knee OA patients can be complemented with clinical balance control tests.

	Total hip and knee arthroplasty	Force-plate analyses of balance following a balance exercise program during acute post-operative phase in individuals with total hip and knee arthroplasty: A randomized clinical trial	Pankaj Jogi, Aleksandra Zecevic, Tom J Overend, Sandi J Spaulding, and Jo hn F Kramer	2	SAGE Open Med. 2016; 4: 2050312116675097	Improvement in balance ability was found on two test conditions that involved standing on both limbs, the anterior lean and posterior lean standing conditions. In conclusion, the addition of three balance exercises to typical joint ROM and muscle-strengthening exercises has potential to improve two-limb standing balance in individuals following THA or TKA as demonstrated by a significant reduction in the 95% ellipse area.
	Rheumatoid arthritis	Forefoot joint damage, pain and disability in rheumatoid arthritis patients with foot complaints: the role of plantar pressure and gait characteristics	van der Leeden M., Steultjens M., Dekker J.H., Prins A.P. and Dekker J.	134	Rheumatology 2006;45:465–469	In this study relationships are identified between foot function on the one hand and joint damage, pain and disability on the other hand, in patients with rheumatoid arthritis-related foot complaints. Forefoot joint damage was significantly correlated with both PP (peak pressure) and PTI (pressure-time integral) under MTP1 and MTP4. Gait parameters, i.e. total contact time and duration of heel loading, were significantly correlated with all disability measures.
Sports Medicine	Ankle ligament injury	Balance and Injury in Elite Australian Footballers	C. Hrysomallis, P. McLaughlin, C. Goodman	88	Int J Sports Med. 2007 Oct;28(10):844-7	It was found that low balance ability was a risk factor for injury to the ankle ligaments. The multivariate analysis revealed that only the mean balance score of both limbs was a significant independent predictor of sustaining an ankle ligament injury, Players with low balance ability had at least twice as many ankle ligaments injuries as those with average or good balance ability.
	Inversion Ankle Sprains	Intrinsic Risk Factors for Inversion Ankle Sprains in Male Subjects	Willems TM, Witvrouw E, Delbaere K, Mahieu N, De Bourdeaudhuij I, De Clercq D.	269	Am J Sports Med. 2005 Mar;33(3):415-23	Results of this study show that especially dynamic stabilizers are compromised in men at risk. We demonstrated that other postural control parameters could predict an ankle injury. Our results show that ankle injuries are more common among men with decreased directional control (limits of stability test). To reduce the amount of ankle sprains in sports activities, we therefore suggest that balance and coordination training should be included in prevention programs.
Vestibular Disorders	Systemic vertigo	Body balance in patients with systemic vertigo after rehabilitation exercise	Mraz M, Curzytek M, Mraz MA, Gawron W, Czerwosz L, Skolimowski T.	26	J Physiol Pharmacol. 2007 Nov;58 Suppl 5(Pt 1):427-36	Patients with vertigo underwent a month-long therapy, which included: exercise of motor-visual coordination on a posturographic platform and balance exercise, which consisted of repeated visual, vestibular, and somatosensory stimulation for conscious postural control. We found a reduction in the range of sways and improvements in visuomotor coordination, and thus also in balance control, and in a subjective feeling of the patient's well-being. Visual stimulation resulted in an increase of the center-of-foot pressure index in the forced standing position with biofeedback and in a decrease of instability.

	Parkinson's disease	Vestibular rehabilitation with computerised dynamic posturography in patients with Parkinson's disease: Improving balance impairment	Rossi-Izquierdo M, Soto-Varela A, Santos-Pérez S, Sesar-Ignacio A, Labella-Caballero T, Rossi-Izquierdo M, Soto-Varela A, Santos-Pérez S, Sesar-Ignacio A, Labella-Caballero T	44	Disabil Rehabil. 2009; 31(23):1907-16	Rehabilitation was performed on 10 patients using computerised dynamic posturography (CDP). These exercises involve visual biofeedback together with sensitive, real-time monitoring of movement. We found statistically significant improvement in the sensorial organisation test (SOT) and the limits of stability and rhythmic weight shift tests measured. we conclude that vestibular rehabilitation in patients with PD is an effective treatment for improving the activities of daily life, gait velocity and balance, as well as reducing the risk of falls. These improvements continue to be statistically significant 1 year post-treatment.
Fall Prevention	Older woman	Fall Incidence in Frail Older Women after Individualized Visual Feedback-Based Balance Training	Sihvonen S, Sipilä S, Taskinen S, Era P.	118	Gerontology. 2004 Nov-Dec;50(6):411-6	Our study is one of the first studies to show that specific balance training can significantly reduce the risk of falling in frail elderly women living in residential care facilities. Our results also indicate that the proportion of recurrent falls was significantly smaller in the EG compared to the CG. In addition, the EG reported decreased fear of falling and increased physical activity after the training period. We showed that frail elderly people can benefit from a carefully targeted training program leading to balance improvements and a reduced incidence of falls.
	Elderly	Effects of Visual Biofeedback Training for Fall Prevention in the Elderly	Kwon-Young Kang	15	J Phys Ther Sci. 2013 Nov; 25(11): 1393–1395.	The individuals in the experiment group selected a biofeedback program at his or her discretion and exercised for 15 minutes, while the individuals in the control group exercised one leg while standing for 15 minutes and then switched legs. The experimental group showed statistically signifcant changes in weight distribution index, stability index, and fall index. According to the comparison of training effects between the two groups, there were statistically signifcant differences in the variables of stability index and fall index.
Plantar pressure map	-	Plantar Pressure Assessment	Margo N. Orlin and Thomas G. McPoil	346	Physical Therapy . Volume 80 . Number 4 . April 2000	Data obtained from a plantar pressure assessment can be used by the physical therapist in the evaluation and management of adult and pediatric patients with a wide variety of foot and lower-extremity disorders associated with the neurological, integumentary, and musculoskeletal systems.

5. Bibliography

The information contained in this manual was partially or fully taken from the work of several authors and sources not being original of the company Sensing Future Technologies. This manual is intended to be a compilation of scientific evidence applicable to the use of PhysioSensing and is currently accessible to anyone. Anyone who reads this manual is able to find more sources of information on this field or contact the original authors.

The sources are:

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Biodex Medical Systems	**Biodex Balance System SD- Clinical Resource Manual 945-308** (PDF) http://www.biodex.com/physical-medicine/applications/fall-risk-screening-conditioning *
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*accessed April 2018