

Vibrotactile Feedback

A Clinical Guideline for using
Vibrotactile Feedback with
Biodex Balance Devices.

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BIODEX

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David Wilcox, OTR/L

David Wilcox is an advanced clinician who has worked in the field of Occupational Therapy for 20 years. He started his career in 1998 at Moss Rehabilitation Hospital in Philadelphia treating clients diagnosed with traumatic brain injury, stroke, spinal cord injury, cardiac, pulmonary, and orthopedic conditions. He expanded his role from treating clinician to student supervisor, guest lecturer, mentor, and adjunct professor with specific focus on neuroscience and cognition. David joined Biodex in 2010. As a clinical instructor, he provides operation-based in-services, clinically focused continuing education courses and workshops, and ongoing clinical support for Biodex's line of physical medicine and rehabilitation products. He continues to work with clinicians and their patients identifying how Biodex technology can effectively assess and target specific impairments contributing to strength, gait, and balance deficits across all populations and diagnoses.

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1. Introduction

Biodex has been providing innovative medical devices and service excellence for more than 60 years. We are especially proud of this accomplishment and earned it the old-fashioned way – by putting our customers and employees first. It all begins with our belief in science-based solutions.

At Biodex, our employees strive to keep our customers at the forefront of the art and science of medicine. It's no wonder so many world-class facilities call Biodex first.

Within this guide, you will find an overview for the application of vibrotactile feedback with recommended treatment strategies. Online eLearning courses are available on the Biodex website:

www.biodex.com/elearning.

An Impairment-Specific Quick Tips Guide, located in the back of this document, is intended to provide treatment strategies at a glance, directly related to specific impairments.

2. Purpose

This Clinical Resource Guideline is intended to be used as a guide and not to supersede clinical judgement or a therapist's decision-making process. The role of the Guideline is to improve patient outcomes as well as increase overall department efficiency. By incorporating traditional examination/evaluation techniques with today's level of technology, Biodex products will assist in maximizing therapist time management and effectiveness. The utilization of standardized, objective testing/training devices can make treatments easily reproducible.

The above, combined with integral research, will assist with the creation of an evidence-based productive practice where tradition and technology meet. Healthcare workers are advised to make individual treatment decisions according to their own judgement in light of each patient's individual circumstances.

3. Overview

Physical and Occupational Therapists are highly trained at identifying and treating motor learning and control impairments contributing to postural instability and falls. Whether from pathology, such as stroke, or just from the natural aging process, therapists utilize a combination of skills to evaluate and treat impairments leading to events such as falls and loss of overall function. An important technique used to target postural control and instability limitations are the use of cues. Traditional types of cues used in the clinic today include, but are not limited to, tactile, visual, and audio.

Biodex balance devices provide therapists with the technology to improve their evaluation and treatment skills. One of the hallmark features of Biodex balance technology is biofeedback, proven to be an effective evaluation and treatment tool for patients with an array of impairments due to pathologies and the natural aging process. In addition to visual and auditory feedback, vibrotactile provides a third and important kind of feedback: somatosensory feedback.

Vibration, a form of touch, is the oldest primitive and pervasive sense that provides immediate, valuable information to our central nervous and musculoskeletal systems with regard to joint position and postural control. According to research, touch, specifically peripheral sensation, seems to be the single most important factor in maintaining static postural stability; hence, somatosensory input can play a vital role in treatment.

Somatosensory feedback provides instant feedback, resulting in the immediate engagement of the motor-learning and control systems required for improved postural control and balance. Vibrotactile feedback is consistent and reproducible – two important variables needed to maximize neuroplasticity and overall patient learning. Objective results from vibrotactile can improve a therapist’s ability to identify postures and movements that contribute to balance and functional limitations, and then design a treatment course specific to those impairments. Additionally, somatosensory feedback may be an effective alternate cueing technique since traditional cueing techniques cannot interpret when there is cognitive and/or language deficit.

Vibration plays an important role in educating patients with movement disorders, which in turn contributes to improved awareness and insight, necessary in the treatment process.

Audio Cueing Versus Vibrotactile Cueing

The Advantage of Audio Cueing:

- Sound can emit through the computer using speakers or headphones.

The Disadvantages of Audio Cueing:

- Sound is directional and can pull postural sway to the source of the sound.
- Many patients have hearing impairments. For example, sensory neural hearing loss diminishes high frequency sound detection.
- Many patients have unilateral hearing loss. To correct for unilateral hearing loss, sound must be amplified in one ear. If uncorrected, sound appears to be sourced in the direction of the able hearing ear.
- The brain requires more time to process sound.
- Hearing is an “already-in-use” sense, or an otherwise occupied sense.

The Advantage of Vibrotactile Cueing:

- Vibration accesses the somatosensory brain cortex – an area already associated with control of postural sway.
- Vibrotactile processing in the brain is quicker than vision or auditory feedback.
- Vibration is the “new” sensation, thus not creating overlay with otherwise used sensory processing.
- Vibrotactile cueing can be coupled with vision and audio feedback, thus creating sensory enrichment for control of postural sway.

4. Pathways to Balance and Postural Control

Balance is the ability to maintain one's center of gravity over their base of support. It is maintained as a result of the interaction of the body's internal receptors in response to the environment. The three main sensory systems involved in the balance process are specifically the visual, vestibular, and the proprioceptive systems. Sensory input from these systems greatly contributes to the quality of balance. The coinciding motor systems are also a major player in the performance of balance.

Throughout the balance process, special nerve endings, called sensory receptors found in our joints and muscles, gather external information. Signals are then sent to the brain stem in the form of nerve impulse. Once the information reaches the brain stem, it is sorted out and integrated with previously learned information, regulated by the cerebellum. As the brain receives these signals, and with proper sensory processing, the brain is then able to pinpoint exactly what the body is doing. It can determine movement, direction, position in space, and balance sense. The end product of normal functional balance is heavily connected to the brain's process of correctly interpreting vast amounts of information. A defect, due to injury or disease, may affect an individual's ability to balance.

Breaking Down the Sensory Systems

Vestibular

The vestibular system is our "movement and balance" sense. The vestibular system helps maintain balance, coordinates head and eye movements and assists with the bilateral integration of the upper and lower extremities. It also assists with interpreting direction and speed of movement while remaining upright against gravity. Vestibular receptors are located in our inner ear (three semi-circular canals), and provide information about movement, balance, body orientation, gravity and vibration. The vestibular system, along with the visual system, assists with maintaining the orientation of head and body in space.

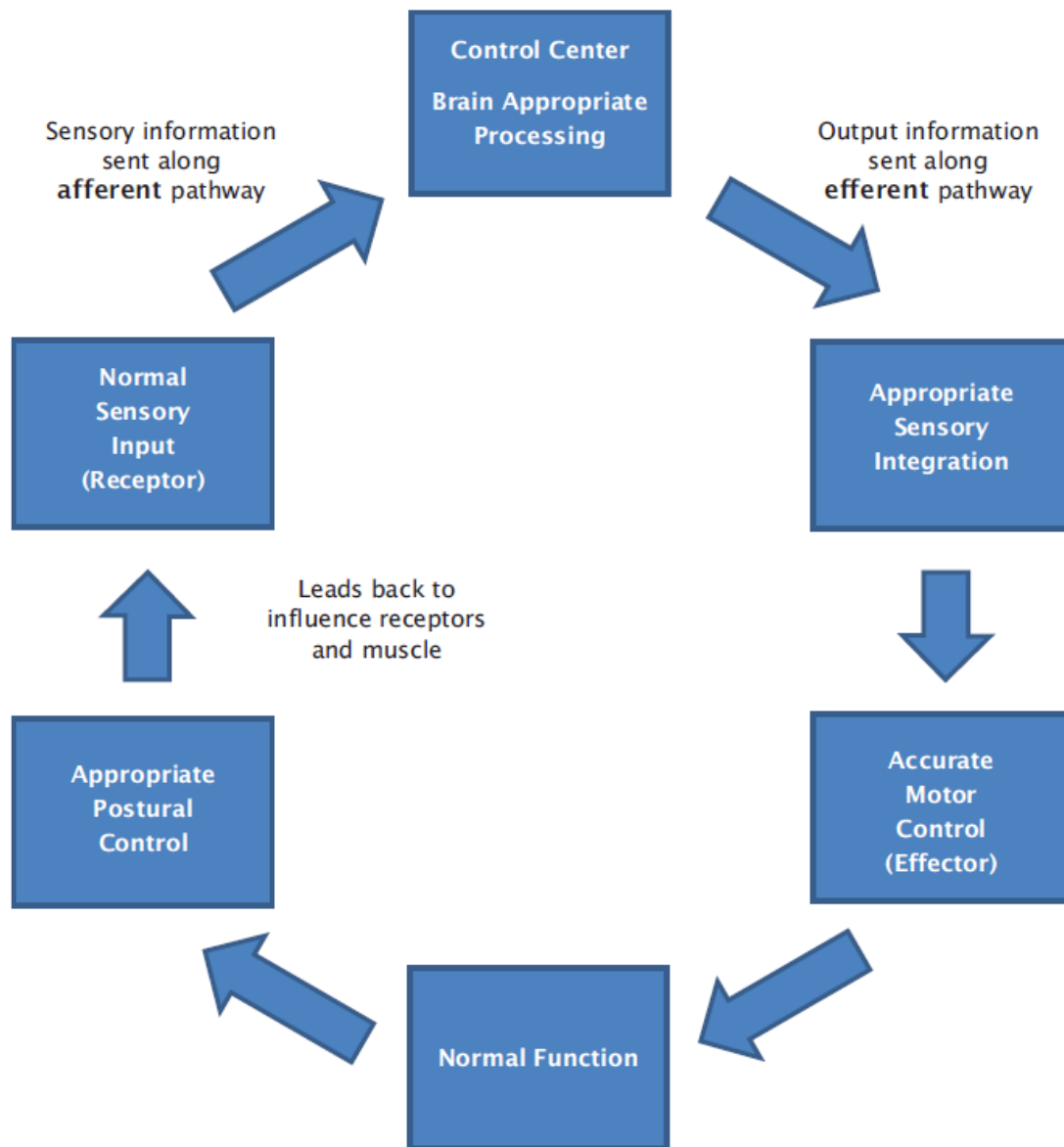
Proprioceptive

The proprioceptive system is responsible for enabling the body to sense movement and identify joint position. Proprioceptive information comes from receptors in muscles, joints, and bones and transmits information regarding body awareness. It also provides information about how we are moving innately. The proprioception system is located primarily in the cerebellum, and works closely with the vestibular system and tactile influence. It is typically activated during resistance-type, active-engagement-of-muscle activities; any movement of the legs, arms, and other body parts will trigger sensory receptors to respond and send impulses to the brain.

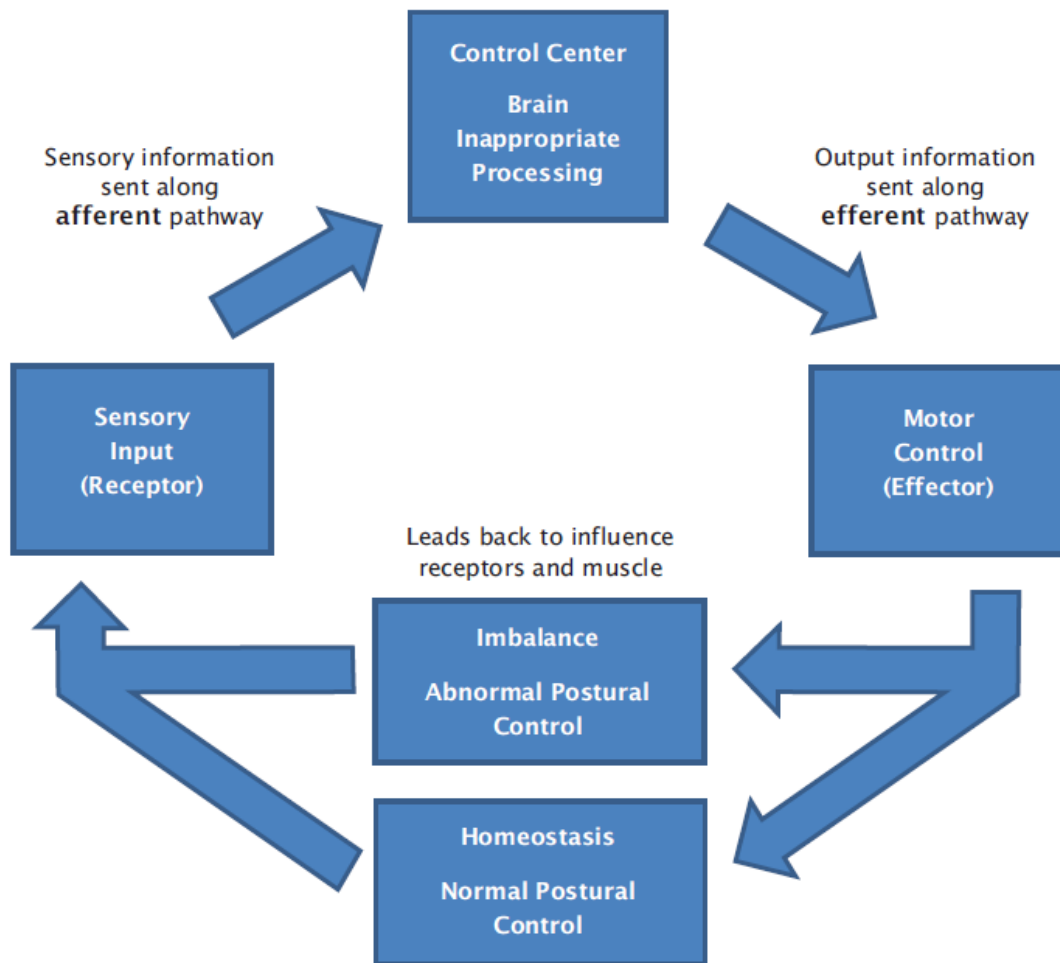
Vision

Vision also plays a significant role in balance. Eyes give a picture of the environment and the relationship to other things in it. In the human visual system, the eye receives physical stimuli in the form of light and sends those stimuli as electrical signals to the visual cortex in the brain, which interprets the signals as images. These images help us respond to the environment. Vision and balance are highly integrated in the brain; visual dysfunctions have a direct effect on postural stability, motion, and function.

Normal Postural Control Pathway



Abnormal Postural Control Pathway



Vibrotactile cueing is very effective in prompting the efferent system to facilitate the motor system to generate the required postural adjustments. The efferent system is comprised of peripheral nerves which link with the muscular system. This then signals the muscular system to generate the necessary postural adjustments, including corrections required after perturbation to stance and gait.

5. Balance and the Role of Vibrotactile Feedback

Functional balance is based on our sensory systems: proprioception, vision and vestibular. When one or more pieces of sensory information are interpreted incorrectly, or a system is not functioning properly, balance may become challenged.

Sensory substitution is a technique that uses a modality to replace or augment another sensory input or information signal that is lacking or not functioning. Vibrotactile feedback is one feedback modality that has been developed to provide individuals with balance problems an external cue about where they are in space. The vibrotactile feedback can also heighten somatosensory awareness and tactile touch. This sensory substitution provides the central nervous system with the necessary information to combat the neural deficits that may occur with disease and aging. Tactile sensory substitution has various applications. Sensory substitution has been applied with varying degrees of success to replace senses lost due to disease or trauma and assists with balance rehabilitation for balance dysfunction. Examples include the use of Braille for the blind and various tactile speech encoders developed for the deaf. Dynamic tactile displays have been demonstrated successfully as both auditory (e.g., TactAid) and visual (e.g., Optacon) substitutes. Vibrotactile displays have also demonstrated to be successful in aviation. For example, a blindfolded pilot can make a complete loop and return to level flight using vibrotactile displays. Another example of sensory substitution can be seen in populations of people that experience anxiety due to balance challenges. During balance training using vibrotactile cues, a feedback loop is produced from the peripheral receptors to the central nervous system. This assists the patient with providing the necessary proprioceptive information via a tactile input. The result is decreased fear of falling, decreased anxiety and improved spatial awareness during balance training.

Research and clinical experience have proven that vibrotactile cueing can tap into brain plasticity. This can enable many patients to process new information and develop new neural pathways. Research and clinical experience also demonstrate that vibrotactile cues that correct postural sway in one situation are retained and transferred to other types of situations. The results of several sets of experiments show that vibrotactile feedback of body tilt can be used to help control body motion under a variety of conditions and tasks.

In summary, utilization of vibrotactile feedback assists with the benefits of motor learning, sensory substitution, and correction of postural sway. It has purpose when targeting vestibular therapies, patients with balance anxieties, and diagnoses of TBI, peripheral neuropathy, amputation and general deficits pertaining to postural control.

6. Adding Vibrotactile to the Plan of Care

Vibrotactile cueing has proven to be an important tool clinicians can use to improve their patient's postural control, overall stability and address many of the deficits of various motor impairments seen in the rehabilitative clinic. The following is recommended for effective outcomes during training with the Biodex VibroTactile™ System:

- Patient should be able to follow simple one-step commands, have adequate sustained, divided, and alternating attention, and ample vision to see the screen on the balance device. They should also be able to effectively communicate (verbally or nonverbally) signs of tolerance.
- Blood pressure, heart rate, and blood oxygen level through pulse oximetry should be within normal limits, in which case the therapist may proceed. If vital signs are unstable, sound clinical judgment to take the appropriate steps is required to assure patient safety.
- If applicable, patients must be able to comply with any precautions dictated by the treating physician.
- Patient should be able to stand for at least 30 seconds and demonstrate minimal ability to perform at least one excursion from their center of pressure with moderate assistance.

In accordance with current motor-learning principles, it is recommended that therapists use vibrotactile cueing as part of their daily treatment on the Biodex Balance System™ SD or BioSway™ balance device. Practice and repetition are imperative for motor learning to occur; movement should be variable and dynamic, stressing active engagement by the patient. Research studies have shown that as little as 15-minutes per day can improve postural control and stability (Basta, et al, 2011). Vibrotactile cueing can be utilized on a daily basis to target any pathology that results in motor learning or postural control deficits contributing to increased sway under static conditions and anticipatory balance problems during dynamic training.

Vibrotactile cues given on the Balance System SD or BioSway are categorized as being attractive or repulsive. Although opposite, they share the same goal: to target and remediate motor and sensory deficits.

- **Attractive cues** instruct patients to move toward the direction of the vibration.
- **Repulsive cues** instruct the patient to move away from the vibration.

Due to the complex nature of the human neurological system, some patients may benefit from one type of cueing while others may benefit from the other. It is the responsibility of the therapist to provide initial and ongoing assessment of the patient, determine objectives, and develop a plan to meet those objectives. The plan may entail testing both types of cueing and assess which one produces the most effective results. Following is a table that identifies which types of training modes utilize attractive cueing and repulsive cueing.

Training Modes – Attractive Versus Repulsive Cueing

Attractive Cueing	Repulsive Cueing
<div data-bbox="285 394 773 667"> <p>Postural Stability Training</p> <p>Time 00:25</p> <p>Score 0</p> <p>Press STOP to End</p> <p>Stop</p> </div> <p data-bbox="418 695 634 726">Postural Stability</p> <p data-bbox="261 751 789 810">Vibration occurs when patient makes contact with therapist-set targets.</p>	<div data-bbox="867 394 1354 667"> <p>Percent Weight Bearing Training</p> <p>Time 00:04</p> <p>% Time On-Target 0%</p> <p>Press STOP to End</p> <p>Stop</p> </div> <p data-bbox="971 695 1260 726">Percent Weight Bearing</p> <p data-bbox="883 751 1349 810">Vibration occurs as patient exceeds the selected boundaries.</p>
<div data-bbox="285 865 773 1138"> <p>Weight Shift Training</p> <p>Time 00:00</p> <p>Score 0</p> <p>Press START to Begin</p> <p>Start</p> </div> <p data-bbox="448 1163 602 1194">Weight Shift</p> <p data-bbox="282 1220 768 1278">Vibration occurs when boundary lines are reached.</p>	<div data-bbox="867 865 1354 1138"> <p>Maze Control Training</p> <p>Time 00:00</p> <p>Score 0</p> <p>Press START to Begin</p> <p>Start</p> </div> <p data-bbox="1024 1163 1195 1194">Maze Control</p> <p data-bbox="846 1220 1373 1278">Vibration occurs when patient moves outside the maze wall.</p>
<div data-bbox="285 1335 773 1608"> <p>Motor Control Training</p> <p>Time 00:10</p> <p>Score 47%</p> <p>Press STOP to End</p> <p>Stop</p> </div> <p data-bbox="440 1629 618 1661">Motor Control</p> <p data-bbox="277 1686 781 1745">Vibration occurs as patient moves through motion pattern within their degree of sway.</p>	<div data-bbox="867 1335 1354 1608"> <p>Random Control Training</p> <p>Time 00:23</p> <p>Score 0%</p> <p>Press STOP to End</p> <p>Stop</p> </div> <p data-bbox="1008 1629 1211 1661">Random Control</p> <p data-bbox="846 1686 1373 1745">Vibration occurs when patient moves outside the boundaries of the red circle.</p>

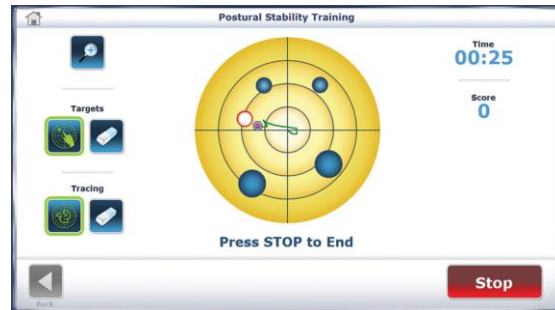
7. Balance Training Modes

NOTE: The VibroTactile System can only be used in training mode.

Attractive Cueing

Postural Stability Training Mode

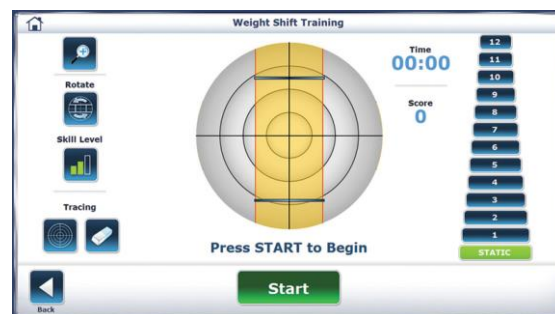
Emphasizes specific movement patterns or strategies by placing markers anywhere on the screen grid. When targets are set, the tactile belt will vibrate when the target is hit. Location of the target will determine which tactor vibrates. When the therapist touches one of the concentric circle-shaped targets, it will become a boundary for the patient to stay within. This mode can be used for patients with impairments in postural stability, with poor movement initiation with random movement patterns, poor weight shifting abilities and an excessive sway envelope.



Skill levels can vary depending upon the location of targets. Patients with poor postural control or fear of falling will feel more secure when the targets are placed closer together as their movement excursion is smaller. When the targets are further apart, greater neuromuscular control is needed to hit each target.

Weight Shift Training Mode

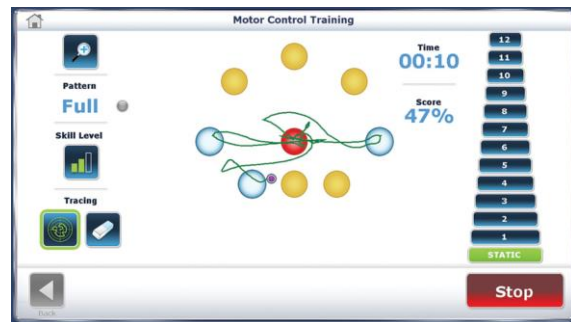
Allows for exercise in the most basic of activities; weight shifting. In this mode, patients have the ability to shift weight in medial/lateral, anterior/posterior and diagonal planes. The target zone is defined by two parallel lines and can be rotated to any of three positions while the amount of excursion within the target area can be modified. In this exercise the tactors will vibrate when either of the two parallel lines are hit.



This mode can be used with orthopedic populations with joint replacements, patients with unilateral lower extremity involvements such as amputees, peripheral nerve involvements and patients with poor movement initiation such as those diagnosed with Parkinson's disease.

Motor Control Training Mode

Challenges the user to move through a movement pattern consistent with the sway envelope. The sway envelope is the area in which a person can move their center of gravity within their base of support. When a patient hits the target on the screen, the tactile belt will vibrate once the patient has entered the circular target. The tactors corresponding with the on-screen targets will vibrate when the patient moves the cursor accordingly.



This mode can be used for patients with movement initiation challenges, rigidity, decreased weight shifting abilities and patients with poor postural stability. The intensity level can be varied by changing the skill level: targets closer together are less challenging. Advanced skill and increased movement control is necessary when the targets are spaced further apart. In addition to full patterns, right and left patterns can be specified for persons that may have unilateral deficits. This mode of training also teaches anticipatory balance control.

Repulsive Cueing

Percent Weight Bearing Training Mode

Provides real time feedback of the percentage of weight bearing on the foot, ankle, knee and hip. In this mode targets can be set that encourage patients to focus on weight bearing in all planes of movement. In the percent weight bearing mode the tactor vibration corresponds with the direction of the patient's movement. The tactor will vibrate when the boundary is exceeded and turn off when the patients stays within the boundary.

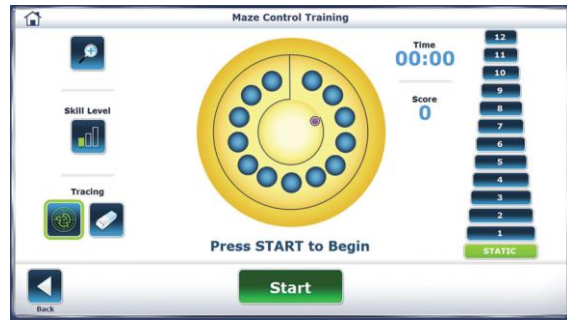


This mode can be used for patients with compromised proprioception, peripheral motor and sensory deficits. Patients performing weight bearing training with the following diagnoses: fractures, joint replacements, amputees and S/P CVA, TBI will benefit greatly from this training mode.

Maze Control Training Mode

Patients follow a reproducible pattern of movement throughout a maze in both static and dynamic environments. Three skill levels create various levels of challenge. The objective of this training is for a patient to move the cursor through the maze, hitting targets. If they hit the maze boundaries, tactors will vibrate until the patient brings the cursor back onto the maze.

This mode can be used for all patients that display various levels of mobility deficits. As with all modes, dual-tasking can increase the challenge of the activity as well as address cognitive skills and anticipatory balance control.



Random Control Training Mode

Patients perform neuromuscular control activities in random patterns generated by the display, ideal for motor control and vestibular training. The size and speed of the target can be modified for progressions ranging from easy to difficult. As patients move to maintain the cursor within the random roaming circle, tactors will vibrate if the cursor falls outside the circle. The vibration will stop when the patient is able to move the cursor back inside the circle.



8. References

Impairment-Specific Quick Tips

VIBROTACTILE BALANCE TRAINING

Impairment	Effect on Balance	Vibrotactile Activated/ Treatment Mode
Decreased core/ LE Strength	<ul style="list-style-type: none"> · Poor postural stability · Poor weight shifting ability · Fear of falling results in poor balance due to anxiety 	<ul style="list-style-type: none"> · Progress as tolerated in order of difficulty · Postural Stability · Weight Shift Mode med/lat/ant/posterior/diagonals · Limits of Stability - small to large excursions · Maze Control · Alter conditions - eyes open, eyes closed, vary platform stability, foot placement, add head movements
Poor Proprioception	<ul style="list-style-type: none"> · Compromised balance · Decreased sensation · Poor WS/WB 	<ul style="list-style-type: none"> · Postural Stability Mode - eyes open, eyes closed, add head movements, vary platform settings · Use for s/p amputee, THR, and TKR · WB/WS Mode - small to large boundaries, vary platform settings
Poor Endurance	<ul style="list-style-type: none"> · Decreased activity tolerance 	<ul style="list-style-type: none"> · Postural Stability Mode - find center, vary small to large excursions, eyes open and eyes closed, vary platform settings

NOTE: The VibroTactile System can only be used in training mode.

Images of the VibroTactile System

For instructions on installation and operations of the Biodex VibroTactile System, please download the manual from the website, www.biodex.com/vibrotactile.



VibroTactile System; including tactile belt, linkbox, and cables.



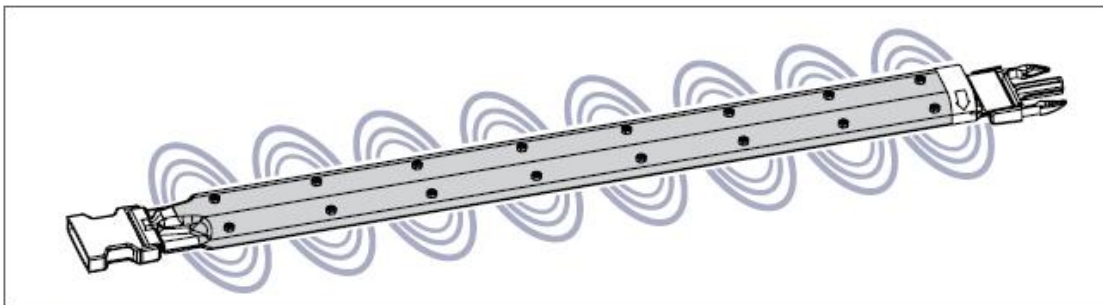
Postural stability training with the VibroTactile System.



Proper positioning of the tactile belt.



Linkbox wireless communication connected to the Biodex Balance System SD sends and receives signals from the tactile belt.



Tactile belt showing factors

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