Biofeedback

Indexing Metadata/Description

› Device/equipment: Biofeedback
› Synonyms: Feedback, psychophysiologic; psychophysiologic feedback
› Area(s) of specialty: Neurological Rehabilitation, Orthopedic Rehabilitation, Women’s Health, Cardiovascular Rehabilitation
› Description/use/terminology
  • Biofeedback is an intervention that provides visual, auditory, verbal or somatosensory feedback to improve a physiological response
  • Biofeedback can be used as an intervention in the management of numerous diagnoses/impairments (e.g., atypical muscle tone, high blood pressure, gastrointestinal disorders, headaches); however, in physical and occupational therapy, biofeedback is implemented predominantly for neuromuscular reeducation\(^1\)
  • Feedback typically refers to clinician-mediated information whereas biofeedback uses an instrument or device\(^2\)
  • When physical and occupational therapists are treating a patient and the goal is neuromuscular reeducation, surface electromyographic (sEMG) biofeedback generally is used\(^1\)
  • sEMG biofeedback
    – Electrodes are positioned over the target muscles and attached to the biofeedback unit\(^1\)
    – Motor unit action potentials (MUAPs) are recorded\(^3\)
    – The intensity of the reading is then translated into auditory or visual feedback for the patient\(^3\)
  • Other forms of biofeedback
    – Manometry – pressure biofeedback\(^4\)
    – Perineometry – pressure of the pelvic floor biofeedback\(^5\) (e.g., vaginal manometry)
    – Temperature biofeedback\(^6\)
    – Pulse oximetry biofeedback
    – Heart rate variability biofeedback
    – Positional biofeedback\(^6\) (e.g., feedback is provided based on a target joint position)
    – Force platform feedback for standing and sway
    – EEG biofeedback – often referred to as neurofeedback
    – Rehabilitative ultrasound imaging (RUSI) – might be used to assess muscle contraction; this method provides visual feedback to both the clinician and patient\(^2\)
      - Unlike other imaging technologies, ultrasound imaging might be considered part of physiotherapy practice\(^8\)
      - RUSI is increasing in popularity among physical therapists as the technology becomes more accessible and affordable for a physiotherapy clinic\(^8\)
    – Nasopharyngoscopic biofeedback for velopharyngeal dysfunction related to cleft lip and palate\(^9\)
Authors of a systematic review of research studies on the availability and usage of electrophysical agents in physiotherapy from 1990 to 2010 reported that biofeedback is one of the most commonly used and available modalities. Availability varied during the review period from highly available and used in England to not available in Australia and Ireland.

Principles of feedback

- The learner gains knowledge and perspective about his or her performance and the outcomes of his or her performance.
- Timing – The ideal timing of feedback (e.g., during the actual task or upon completion of the task) for the advancement of motor learning has yet to be fully established.
- Frequency – The consensus appears to be that feedback should not be provided after a patient’s every try at a task; however, the ideal frequency of feedback has not been established for every form of biofeedback (e.g., RUSI).

CPT codes

- 97112 neuromuscular reeducation of movement, balance, coordination, kinesthetic sense, posture and/or proprioception for sitting and/or standing activities

Reimbursement: Biofeedback therapy is covered under Medicare for the treatment of spasticity, and neuromuscular re-education of specific muscle groups. The therapy is not covered for muscle tension treatment or psychological disorders.

Indications for device/equipment

- Biofeedback might be implemented in an effort to bring about a variety of patient outcomes; examples include:
  - Neuromuscular reeducation
  - Adaptations in an individual’s behavior
  - Relaxation
  - Pain reduction
  - Better performance during sporting activities

- Biofeedback has been used in the management of numerous conditions; examples include:
  - Stroke
  - Spinal cord injury (SCI)
  - Myofascial pain
  - Complex regional pain syndrome
  - Low back pain
  - Arthritis
  - Headaches
  - Hypertension
  - Drug addiction
  - Bruxism
  - Gait deviations related to various causes (e.g., impaired compliance with postsurgical weight-bearing, impaired ROM secondary to spasticity)
  - Urinary incontinence
  - Bell’s palsy
  - Temporomandibular disorders
  - Dysphagia

Advantages of biofeedback

- Noninvasive procedure
- Might be an effective substitute for certain medications; this is particularly useful when medications have not been very effective or when a woman is pregnant.
- It enables patients with chronic pain to achieve an improved sense of self-control and self-efficacy.
Use of biofeedback in telerehabilitation has been found useful and appropriate for treating poststroke patients at home after an initial phase in hospital\(^{20}\)

- A telerehabilitation tool for use by poststroke patients for upper limb motor recovery involves use of biofeedback\(^{21}\)
- Trials to assess the effectiveness of this tool have been proposed in Italy\(^{21}\)

### Guidelines for use of device/equipment

Clinicians should follow the guidelines of their clinic/hospital and what is ordered by the patient’s physician. The summary on EMG listed below is meant to serve as a guide, not to replace orders from a physician or a clinic’s specific protocols.

#### EMG

- Using a bipolar setup, there are 3 electrodes in total (2 active, 1 reference)\(^{2}\)
  - Typically, the active electrodes are positioned proximal to or over the affected muscle(s) motor point and are within 1 to 5 cm of each other
  - The reference electrode is positioned in close proximity to the targeted area
  - When treating a patient with reduced strength, starting off with the electrodes further apart might be advantageous; when attempting to isolate an individual muscle, placing the electrodes nearer to each other might be beneficial
  - The sensitivity of the biofeedback unit can be reduced, which can further challenge the patient
  - Duration of the biofeedback training is largely dependent on patient tolerance (can range from 5 minutes to a half hour or more)
- To assess the pelvic floor muscles, surface, vaginal, and anal electrodes might be used during EMG\(^{22}\)

#### Weight-bearing

- A force plate under the feet is used to detect changes in weight bearing (e.g., center of pressure [COP] displacement), and tilt angles in real time

### Contraindications/Precautions to device/equipment

Additional training for physical and occupational therapists is necessary prior to providing rehabilitation for bowel, bladder, and/or gynecological dysfunction\(^{23}\)

Therapists are also advised to check state practice acts/regulatory guidelines as well as individual establishment guidelines before treating individuals for bowel, bladder, and/or gynecological dysfunction\(^{23}\)

The therapist should be aware of any allergies/skin sensitivities that the patient might have prior to selecting biofeedback mechanism (e.g., EMG, ultrasound)\(^{1}\)

The clinician should abide by the precautions/contraindications listed by the manufacturer for each specific biofeedback device used during treatment. Precautions/contraindications can vary depending on the type of biofeedback utilized\(^{2}\)

Clinicians should consider the following, prior to implementing biofeedback\(^{3}\)

- The patient needs to be able to effectively communicate
- The patient’s hearing or vision must be intact to use auditory or visual biofeedback
- The patient must demonstrate good comprehension of simple commands
- The patient must demonstrate the ability to concentrate and focus on specific tasks
- The patient should be free from significant sensory and/or proprioceptive impairment
- The patient should have intact motor planning skills

See specific contraindications/precautions under Examination and Assessment/Plan of Care

### Examination

#### Contraindications/precautions to examination

- History taking and examination procedures are dependent on the underlying condition and reason for referral.
  - The information listed below is meant to serve as a guide/overview. Clinicians should supplement or modify the recommendations listed below as indicated and appropriate given the unique circumstances of the patient
- Strictly adhere to weight-bearing status prescribed by physician
- The need for a fall-safety program will depend upon the diagnosis and reason for referral. Utilize fall-safety protocol and precautions until safety can be fully confirmed
History
• History of present illness/injury for which the device is needed
  – Mechanism of injury or etiology of illness: What is the current reason for referral?
  – Course of treatment
    - Medical management: Medical management will vary widely depending on the specific underlying condition; document any reported diagnostic tests, therapeutic interventions, and/or hospital stays
    - Medications for current illness/injury: Determine what medications the physician has prescribed; are they being taken?
    - Diagnostic tests completed: Diagnostic tests will depend on suspected underlying condition
    - Home remedies/alternative therapies: Document any use of home remedies (e.g., ice or heating pack) or alternative therapies (e.g., acupuncture) and whether or not they help
    - Previous therapy: Document whether patient has had occupational or physical therapy or chiropractic treatment for this or other conditions, and what specific treatments were helpful or not helpful. Document any prior use of biofeedback for any reason. Document any prior use of surface electrodes including EKG, EEG, and surface stimulation and any skin reactions
  – Aggravating/easing factors (and length of time each item is performed before the symptoms come on or are eased): Document any reported aggravating or easing factors
  – Body chart: Use body chart to document location and nature of symptoms
  – Nature of symptoms: Document nature of symptoms (e.g., constant vs. intermittent, sharp, dull, aching, burning, numbness, tingling)
  – Rating of symptoms: Use a visual analog scale (VAS) or 0–10 scale to assess symptoms at their best, at their worst, and at the moment (specifically address if pain is present now and how much)
  – Pattern of symptoms: Document changes in symptoms throughout the day and night, if any (A.M., mid-day, P.M., night); also document changes in symptoms due to weather or other external variables
  – Sleep disturbance: Document number of wakings/night related to condition as applicable
  – Other symptoms: Document other symptoms the patient is experiencing that could exacerbate the condition and/or symptoms that could be indicative of a need to refer to physician (e.g., dizziness, saddle anesthesia)
  – Respiratory status: Is there any respiratory compromise? Any past or present use of supplemental oxygen or mechanical ventilation?
  – Barriers to learning
    - Are there any barriers to learning? Yes__ No__
    - If Yes, describe _______________________
• Medical history
  – Past medical history
    - Previous history of same/similar diagnosis: Document any prior use of biofeedback for current or other condition and whether or not it was effective
    - Comorbid diagnoses: Ask patient about other problems/conditions, including diabetes, cancer, heart disease, complications of pregnancy, allergies, psychiatric disorders, orthopedic disorders, and hearing or visual impairment
    - Medications previously prescribed: Obtain a comprehensive list of medications prescribed and/or being taken (including over-the-counterdrugs)
    - Other symptoms: Ask patient about other symptoms he or she is experiencing
    - Past surgical history: Inquire about any previous surgeries
• Social/occupational history
  – Patient’s goals: Document what the patient hopes to accomplish with therapy and in general
    - Patients’ goals are generally to reduce symptoms and achieve a more “normal” state, whereas athletes tend to seek biofeedback to improve performance in a specified sport or task(23)
    - Correction of abnormal movement patterns for the purpose of improved social wellness might be included in goals for using biofeedback (e.g., “to walk more normally”)(24)
  – Vocation/avocation and associated repetitive behaviors, if any: Does the patient participate in recreational or competitive sports? Does the patient work or attend school? Is the patient unable to work or participate in desired activities because of the problems he or she presents with?
  – Functional limitations/assistance with ADLs/adaptive equipment: Inquire about limitations with self-care, home management, work, community, and leisure
Living environment: Document information about the living environment including stairs, number of floors in home, and with whom patient lives (e.g., caregivers, family members). Identify if there are barriers to independence in the home; any modifications necessary?

Relevant tests and measures: (While tests and measures are listed in alphabetical order, sequencing should be appropriate to patient medical condition, functional status, and setting.) Evaluation procedures should be modified according to the patient’s age, diagnosis, and any unique circumstances; the information listed below is meant to serve as a guide only. Complete a general evaluation as indicated and appropriate:

- Arousal, attention, cognition (including memory, problem solving): Assess to help determine if patient is appropriate candidate for biofeedback
- Assistive and adaptive devices: Does the patient utilize any assistive or adaptive devices? Are they appropriate?
- Balance: Assess the patient’s balance in sitting and standing (statically and dynamically) as indicated; Berg Balance Scale can be used for objective measurement
- Cardiorespiratory function and endurance: Assess vital signs as indicated and appropriate
- Circulation: Assess for signs of diminished circulation and/or deep vein thrombosis (DVT)
- Ergonomics/body mechanics: Assess for faulty body mechanics and muscle recruitment, as well as posture during work, ADLs, and leisure activities, which might be contributing to the patient’s pain
- Functional mobility: Assess function as indicated by underlying condition; the FIM or Timed Up and Go (TUG) test can be used for objective measurement
- Gait/locomotion: Complete a thorough gait assessment as indicated by reason for referral; the Dynamic Gait Index (DGI) can be used to assess ambulation safety. Assess running as indicated
- Joint integrity and mobility: Assess joint integrity and mobility as indicated by symptoms and reason for referral
- Motor function (motor control/tone/learning):
  - Assess muscle tone and perform motor control assessment including coordination as indicated
  - RUSI could potentially be used to evaluate muscular integrity and function (e.g., signs of atrophy, disproportionate use of certain muscles); however, the reliability of RUSI as a means to assess patient outcomes requires further investigation
- Muscle strength: Complete a thorough strength assessment throughout with a particular focus on the area where biofeedback is to be applied
- Observation/inspection/palpation (including skin assessment): Observe treatment area; note any atypical findings. Palpate for bony and/or soft tissue abnormalities; inspect skin integrity before and after treatment. Skin sensitivity to electrode materials, conducting media, or adhesive might occur
- Perception (e.g., visual field, spatial relations): Complete assessments as indicated; this is particularly important when implementing a visual form of biofeedback
- Posture: Observe general posture and note any deviations
- Range of motion: Complete a ROM assessment with a focus on the treatment area
- Reflex testing: Assess deep tendon reflexes as indicated
- Self-care/activities of daily living (objective testing): Complete an ADL and self-care assessment as indicated
- Sensory testing: Complete a sensory assessment as appropriate and indicated (e.g., light touch, proprioception), especially where biofeedback is to be utilized
- Special tests specific to diagnosis: Implement special tests as indicated by condition

Assessment/Plan of Care

- Contraindications/precautions:
  - Clinicians should follow the guidelines of their clinic/hospital and what is ordered by the patient’s physician. The summary below is meant to serve as a guide, not to replace orders from a physician or a clinic’s specific protocols
  - Patients who need this device or those with a diagnosis for which this device is used might be at risk for falls; follow facility protocols for fall prevention and post fall-prevention instructions at bedside, if inpatient. Ensure that patient and family/caregivers are aware of the potential for falls and educated about fall-prevention strategies. Discharge criteria should include independence with fall-prevention strategies
  - Known allergy to electrode gel or medical adhesive used on electrodes is a contraindication
  - See specific contraindications/precautions under Contraindications/Precautions to device/equipment

- Diagnosis/need for device/equipment: In physical and occupational therapy, biofeedback is implemented predominantly for neuromuscular reeducation; please see Indications for device/equipment, above, for more details
Prognosis: Prognosis will vary widely depending on underlying condition and severity of condition.

Referral to other disciplines: Refer to other disciplines (e.g., speech therapy, psychology) as indicated and appropriate.

Other considerations:
- Existing biofeedback approaches rely largely on audio and visual cues that typically are presented to the user on a computer screen or a mobile phone interface. Researchers are investigating the use of animatronic biofeedback to improve the response of patients who have difficulty using and understanding the typically used interfaces.

Treatment summary:
- Impairments of gait, balance, and lower extremity function
  - The use of biofeedback is superior to usual therapy and placebo at improving activities of the lower limb following stroke.
    - Based on a systematic review with meta-analysis of randomized trials
    - 22 trials involving 591 participants investigated biofeedback as an intervention to improve lower limb activities after stroke.
    - Activities trained included standing up, standing, and walking.
    - Outcome measures included weight distribution between lower limbs, directional control during reaching, Berg Balance Scale, and components of functional scales such as the Fugl-Meyer or Rivermead.
    - There is evidence that biofeedback has a moderate effect in improving activities of the lower limb in the short term compared with usual therapy, and the benefits are still present in the longer term although slightly diminished.
    - This suggests that in addition to short-term improvements in performance, learning has taken place.
    - It appears that use of biofeedback is superior to therapist feedback at improving lower limb activities after stroke.
  - Authors of a systematic review of biofeedback for training balance and mobility in older adults did not find sufficient studies to make definitive statements about its effectiveness in this population.
  - Biofeedback interventions could be compromised in older adults with balance or mobility disorders due to existence of comorbidities.
  - Disabling health conditions and declines in sensory functioning and/or cognitive functioning might contribute to difficulties in processing of biofeedback signals.
  - The available studies provide limited information on whether biofeedback-based training of balance and mobility in older adults has an effect on disability and functioning.
  - Further studies are needed to evaluate the added effectiveness and feasibility of biofeedback interventions in geriatric populations other than those who are post stroke or lower limb surgery.
  - Authors of a multicenter pilot study in the United States investigated biofeedback treatment for balance post stroke via the use of a new tongue electrotactile feedback device to overcome the limitations of conventional feedback training.
    - The device transmits head position information in real time through a pattern of stimulation on the tongue.
    - 29 chronic stroke patients participated in an 8-week program using the device.
    - There were statistically and clinically significant improvements in results of the Berg Balance Scale, the TUG test, the DGI, the Activities-specific Balance Confidence (ABC) Scale, and some domains of the Stroke Impact Scale.
    - Electrotactile biofeedback appears to be an effective method for balance training. Randomized controlled studies are needed.
  - Researchers in Poland conducted a randomized clinical trial to evaluate the effects of gait training with and without visual biofeedback in patients in the late period after stroke.
    - 50 patients at least 6 months post stroke were randomly assigned to the intervention group (treadmill training with visual biofeedback) or the control group (treadmill training without any biofeedback).
    - Outcome measures included spatio-temporal gait parameters, walking speed, walking distance, self-reliant mobility, and functional capacity.
    - 10 sessions were performed over a 2-week period.
    - Compared to the control group, participants in the intervention group demonstrated significantly greater improvement in shortening of the stance phase and lengthening of the swing phase of the unaffected limb.
    - No other significant differences between groups were noted.
  - Balance training involving visual feedback using Wii Fit after stroke led to improvement in body symmetry, balance, and function in a study conducted in Brazil; however, the improvements obtained were similar to those obtained with conventional physical therapy.
    - 20 adults with hemiplegia following a stroke participated.
- Outcome measures included the Berg Balance Scale, the TUG test, the FIM, and body symmetry
- No statistically significant differences were found between the experimental and control groups

In a study to evaluate electrical activation of the quadriceps muscles during weight-bearing tasks using the Wii Fit Plus, researchers in Brazil found that real-time feedback did not alter quadriceps activation during the Wii tasks and that these games showed EMG activation levels similar to those for the same tasks outside the virtual environment (91)

- 30 healthy volunteers participated
- Activation of quadriceps muscles was recorded during lunge, single leg extension, and single leg reach while exercises were repeated with visual feedback, with auditory feedback, and with no feedback
- There were no significant differences among the 3 feedback conditions

Authors of a 2011 systematic review of the evidence on the effectiveness of EMG biofeedback for the quadriceps femoris in treating various knee conditions found that EMG biofeedback appeared to benefit short-term postsurgical pain or quadriceps strength but was ineffective for chronic knee conditions (28)

- 8 studies with a total of 319 participants were included. Diagnoses included patellofemoral pain syndrome, anterior cruciate ligament repair, arthroscopic surgery, and osteoarthritis (OA)
- EMG biofeedback of the quadriceps femoris demonstrated potential improvements in knee extensor torque and functional outcome after ACL reconstruction or meniscectomy
- Chronic knee conditions such as OA and patellofemoral pain did not benefit from EMG biofeedback
- Further investigation is warranted due to the small number of included studies and large variability in patient population, interventions, and outcomes

Authors of a 2012 systematic review of EMG biofeedback on quadriceps strength compared to placebo and traditional exercise in both healthy populations and populations with pathology found that current literature cannot definitively support its use (62)

- It is unclear whether EMG biofeedback has a greater effect than traditional strength training alone on increasing quadriceps strength in either population
- The addition of EMG biofeedback to an isometric exercise program has been reported to produce greater increases in muscle strength, greater reduction in pain intensity, and more improvement in functional status compared to isometric exercise alone in patients with OA of the knee (29, 30, 83)

- In a randomized controlled trial conducted in India, 30 patients with knee OA were randomized to a biofeedback group or a control group (30)
  - The biofeedback group received EMG biofeedback during isometric exercises of the quadriceps and hip abductors, 5 days a week for 3 weeks. The control group received the same exercises
  - Outcome measures were a pain VAS and the reduced WOMAC scale
  - Patients receiving biofeedback showed significantly greater improvement in both the VAS and the WOMAC
- In another randomized controlled trial conducted in India, 33 knee OA patients were randomized to a biofeedback group or a control group (29)
  - The biofeedback group received EMG biofeedback during isometric exercises 5 days per week for 5 weeks. The control group received the same exercises without biofeedback
  - The increase in maximum isometric quadriceps strength was greater in the group receiving biofeedback
- Authors of a randomized controlled trial in Korea studied the effects of biofeedback on maximum voluntary isometric contraction (MVIC), pain, and muscle thickness in 30 older females (> 65 years) with knee OA (83)
  - Patients were divided into 3 groups. Group 1 received electromyographic biofeedback (EMGBF) training, group 2 received ultrasound biofeedback (USBF), and group 3 served as the control receiving a hot pack, ultrasound, and transcutaneous electrical nerve stimulation (TENS)
  - Subjects in each group received treatment for 20 minutes, 3 times a week for 8 weeks
  - Outcome measures included MVIC, pain using a VAS, and vastus medialis oblique thickness
  - MVIC showed significant increases in the EMGBF and USBF groups compared to the control group. The VAS pain rating significantly decreased in the EMGBF and USBF groups compared to the control group. Only the EMGBF group showed a significantly increased VMO thickness compared to pre-training
- Biofeedback might be beneficial to promote movement symmetry after total knee arthroplasty (TKA) (63)

- Based on a study conducted in the United States that compared biomechanical and functional metrics of patients who received movement symmetry biofeedback during outpatient rehabilitation to a control group that did not receive specialized symmetry training
Asymmetries after TKA increase load on the nonoperated limb and are associated with worse functional outcomes. Patients who received added symmetry training were found to have mean sagittal knee movements that were more symmetrical, biphasic, and more representative of normal knee kinetics 6 months post TKA.

Researchers in the United States investigated the effects of weight-bearing biofeedback training on functional movement patterns after TKA in a randomized controlled trial. 26 patients were randomly assigned to receive standard of care augmented with weight-bearing biofeedback training or dose-matched standard of care rehabilitation. Outcome measures included lower limb weight-bearing ratios measured during the 5-times sit-to-stand test (FTSST) and during walking, as well as FTSST scores, walking speed, and lower limb joint moments. Results indicated that the biofeedback did not have an effect on functional weight-bearing symmetry or on knee extension moments during the FTSST, but that it did result in increases of knee extension moments during gait as well as improved scores on the FTSST.

Researchers in Canada compared the effectiveness of mirror training, raw video, and real-time visual biofeedback for training toe-out gait in individuals with knee OA. A repeated-measures, within-subject trial was performed on 20 subjects. Participants were trained to walk on a treadmill while matching a target indicating a 10-degree increase in stance phase toe-out compared to the toe-out angle measured during habitual walking. All subjects performed a trial each of the 3 types of feedback (mirror, raw video, and real-time visual biofeedback) in random order. Real-time biofeedback demonstrated a significant decrease in toe-out performance error compared to the other feedback groups.

Biofeedback relaxation is effective for decreasing pain associated with continuous passive motion (CPM) in patients post TKA. 66 patients were included post TKA while admitted to a general hospital in Taiwan. Patients were randomly assigned to the intervention group (biofeedback during CPM) or the control group (CPM without biofeedback). Pain was measured before and after each CPM session, which occurred twice daily for 5 days. A numeric pain rating scale was used to measure perceived pain. The biofeedback group demonstrated significantly less pain with CPM compared to the control group.

Biofeedback might facilitate patient compliance with partial weight-bearing (PWB) status. Based on a randomized controlled trial comprising 33 subjects conducted in Israel. All subjects had recently undergone surgery or had experienced a fracture and as a result had PWB status. Touch down weight-bearing was defined as up to 20% of body weight. PWB was defined as 21–50% of body weight. Subjects were randomized to one of two treatment groups; both received daily 45-minute treatment sessions for 10 days. Intervention group: Audio and visual feedback (through a computer) was provided in an effort to facilitate compliance with weight-bearing status when the patient was standing; audio feedback was provided during ambulation. Control group: Verbal instruction/cueing on maintenance of weight-bearing status. Results: The subjects in the intervention group experienced a significant improvement in ability to comply with weight-bearing status; this was not true for the control group. Because many PWB orthopedic patients are of advanced age, a study to test the effect of age on PWB biofeedback training was conducted in the United States. 50 asymptomatic individuals between 20 and 78 years of age participated. PWB training with verbal instructions, a bathroom scale, and a biofeedback device were compared. Age was not a significant predictor of compliance. Biofeedback training leads to superior compliance to weight-bearing instructions and might be appropriate in any age group.

Researchers in the United States investigated the effects of haptic (vibratory/vibrotactile) biofeedback on lower-extremity partial weight bearing. 30 healthy participants were randomly assigned to 1 of 3 groups: verbal instruction, bathroom scale training, and haptic biofeedback.
- The haptic biofeedback group averaged significantly better outcomes for partial weight-bearing compliance compared to either control group
- The effect of biofeedback on partial weight-bearing compliance is maintained over the course of 24 hours\(^\text{(64)}\)
- Based on a study involving 14 participants conducted in the United States
- 12 participants were trained with a biofeedback device to comply with touch weight-bearing instructions. Two control participants were given no biofeedback training
- Weight-bearing was assessed for each participant immediately following training and at 2–4, 6–8, and 22–24 hours
- Participants who received biofeedback bore the appropriate amount of weight after training. Control subjects bore significantly greater weight than instructed
- Tests conducted during the 24-hour period showed no significant difference from the original testing
- In patients with full weight-bearing (FWB) status, utilizing the SmartStep (with biofeedback) might lead to improved weight shifting/loading over the impaired extremity\(^\text{(32)}\)
- Based on a two-part study conducted in Israel that investigated the validity of the SmartStep and its efficacy as a biofeedback tool
  - SmartStep
    - From Andante Medical Devices, Ltd.
    - The instrument fits in the patient’s shoe and assesses body weight
    - Also provides biofeedback
  - Part one
    - 11 healthy individuals participated in the study
    - Measurements from the SmartStep were judged against those gathered from a force plate
    - There was a statistically significant correlation between the two instruments
  - Part two
    - 42 individuals undergoing rehabilitation took part in the study
    - Participants were randomized to one of two groups (each was given FWB status)
      - Treatment group – auditory feedback was provided when the predetermined weight was detected by the SmartStep
      - Control group – standard weight-bearing training
    - The individuals in the treatment group experienced a significant improvement in weight-bearing (impaired extremity) when measured against the control group
- Balance exercises via force platform biofeedback coupled with standard rehabilitation for individuals with poststroke hemiparesis might lead to larger gains in postural control and the ability to bear weight through the impaired extremity than with standard rehabilitation alone\(^\text{(33)}\)
- Based on a randomized controlled trial in Turkey involving 41 subjects with a median of 6 months since stroke
- The subjects were randomized to one of two groups
  - Treatment group – balance training and standard rehabilitation
    - Balance training – 15 sessions; 5 days/week, 15 minutes/day, duration of 3 weeks; a force plate linked to a monitor providing visual feedback was used
    - Standard rehabilitation – 5 days/week, 2–5 hours/day, duration of 8 weeks
  - Control group – standard rehabilitation only
- Results
  - The treatment group experienced a significantly greater improvement in frontal plane pelvic excursions and a significantly greater increase in vertical ground reaction force through the impaired extremity
- Researchers in Poland compared the effectiveness of posturographic platform biofeedback training to conventional therapy in 21 patients post stroke\(^\text{(76)}\)
- Dynamic balance was measured with the TUG test
- Post interventions, balance scores of patients in the biofeedback group were significantly higher than those of the conventional therapy control group
- Greater improvements with biofeedback training were observed in participants who experienced a left hemispheric stroke with right-sided hemiparesis compared to participants who had sustained a right hemispheric stroke and left-sided hemiparesis
- Spinal stabilization with visual feedback has been reported to be an effective intervention for improving balance\(^\text{(34)}\) and mobility\(^\text{(35)}\) in chronic stroke patients
In a randomized controlled trial conducted in the Republic of Korea, 21 chronic stroke patients were randomized to a group receiving conventional physiotherapy or a group performing spinal stabilization exercises 30 minutes per day, 5 days per week for 8 weeks while receiving visual information about abdominal muscle output. Output measures included temporal and spatial gait parameters and Berg Balance Scale and TUG test scores.

Researchers concluded that biofeedback functional electrical stimulation (BF-FES) with mirror therapy resulted in significant improvement in upper extremity motor recovery and improved quality of life post stroke.

29 patients post stroke (> 6 months prior) were randomly assigned to 1 of 3 groups: BF-FES plus mirror therapy, functional electric stimulation (FES) plus mirror therapy, or conventional therapy without BF-FES or FES.

The BF-FES group showed significant improvement in wrist extension (ROM) and strength (MMT). The BF-FES group also demonstrated significant improvement in the Box and Block Test (BBT), Jebsen Taylor Hand Function (JTHF), and Stroke Specific Quality of Life (SSQOL) when compared to both of the other groups.

Real-time biofeedback of kinematic data during treadmill walking was reported to be effective at correcting gait patterns in a study conducted in the United States.

Knee hyperextension gait patterns are associated with increased stress to the posterior capsule of the knee and increased risk of anterior cruciate ligament injury in female athletes.

Gait training to correct knee hyperextension using real-time kinematic data (Visual 3D) was provided for 6 sessions to 10 young women with asymptomatic knee hyperextension.

Participants showed improved control of knee hyperextension during overground walking immediately after training and at 1 month post training.

Real-time biofeedback can reduce knee adduction moment in patients with knee osteoarthritis who are undergoing gait retraining.

Based on a systematic review of 12 studies, evidence for the use of real-time biofeedback for gait retraining in healthy controls was strong; evidence for patients with osteoarthritis is limited, but promising.

Limitations of the review were that most studies were small and all but one were uncontrolled/nonrandomized.

Authors found insufficient evidence to determine the optimal means of delivery for biofeedback.

The addition of EMG biofeedback to standard rehabilitation in children with cerebral palsy might lead to superior functional outcomes when compared to standard rehabilitation alone.

36 children participated in the trial; all had a diagnosis of spastic cerebral palsy and dynamic equinus deformity.

The children were randomized to one of two groups:

- Treatment group – EMG biofeedback and a standard exercise program for 10 days
  - Biofeedback was utilized for 30 minutes each day; subjects received auditory and visual feedback with the goal of contracting the ankle dorsiflexors and simultaneous relaxation of the ankle plantar flexors.
  - The standard exercise program lasted 2 hours per day
- Control group – standard exercise program for 10 days (2.5 hours per day)

Results – when comparing the two treatment arms post intervention:

- The treatment group experienced significantly greater improvements in muscle tone and ankle dorsiflexion (both with the knee flexed and extended).
- The treatment group experienced significantly greater improvements in the Clinical Gait Assessment, stride length, and cadence.

EMG biofeedback training of gluteus maximus muscles might improve gait parameters and EMG amplitude in patients with incomplete SCI.

Based on a randomized controlled study involving 30 patients with incomplete SCI conducted in India:

- Patients were randomly assigned to receive EMG biofeedback training of the gluteus maximus along with standard care and gait training, or standard care and gait training alone.
- After training, EMG amplitude, walking velocity, and cadence were significantly greater in the group receiving biofeedback. There was no significant difference in step length.

There is some evidence that adding biofeedback to a pelvic floor muscle training program is beneficial for treatment of urinary incontinence in women.
A Cochrane systematic review of randomized or quasi-randomized trials in women with stress, urgency or mixed urinary incontinence reviewed 24 trials involving 1,583 women.

Biofeedback was provided using a vaginal or anal device to measure squeeze pressure or electrical activity and to generate an auditory or visual signal.

Women who received biofeedback were significantly more likely to report that their urinary incontinence had been cured or improved compared to women who received pelvic floor muscle training alone.

Women who received biofeedback typically had more contact with the health professional than those not receiving biofeedback with their training, so it is not clear whether this effect was due to the biofeedback itself or from spending more time in clinic.

Investigators conducted a systematic review of the effectiveness and cost effectiveness of nonsurgical treatments for women with stress urinary incontinence compared pelvic floor muscle training with and without biofeedback, electrical stimulation, vaginal cones, bladder training, and serotonin-noradrenaline reuptake inhibitor medications.

Basic pelvic floor muscle training (maximum 2 sessions per month) was more effective than no treatment only when success was defined as improvement not cure.

Pelvic floor muscle training in a more intense fashion, either by adding extra sessions or by adding biofeedback, appeared to be the most effective treatment.

More intensive forms of pelvic floor muscle training appear to be worthwhile; however, it is not clear if the effectiveness is due to biofeedback specifically or spending more time in treatment.

Biofeedback appears to be more cost-effective than surgery, but the authors point out that therapists must be specially trained to implement biofeedback and that its costs must be considered.

An earlier systematic review found that available evidence regarding the efficacy of biofeedback in conjunction with pelvic floor muscle reeducation (vs. pelvic floor muscle reeducation alone) for the management of urinary incontinence is inadequate, prohibiting the ability to draw firm conclusions on its implementation for this condition.

The review included 11 studies involving a total of 816 individuals.

Types of biofeedback examined in this review included variations of EMG and pressure biofeedback.

Use of a perineometer to provide feedback regarding pelvic floor contraction strength resulted in greater pelvic floor muscle strength gains than pelvic floor muscle training alone in women with urinary stress incontinence.

Perineometer training was more effective than pelvic floor exercises alone in reducing urinary stress incontinence in a quasi-experimental pretest posttest comparative study.

Results of a study conducted in the United States to determine the important elements of biofeedback for urge incontinence indicate that responders can be identified early in treatment, allowing for fewer sessions.

Based on a secondary analysis of a noncontrolled trial of biofeedback-assisted pelvic floor muscle exercises.

For 130 subjects who completed 7-day bladder diaries, biofeedback resulted in a reduction of incontinence episodes from a mean of 3.2 in a 24-hour period to a mean of 1.0 in 24 hours.

The main improvement occurred after the first feedback session.

EMG biofeedback-assisted pelvic floor muscle training for stress urinary incontinence has been reported to improve quality of life in women who are capable of pelvic floor muscle contraction. Additional electrical stimulation was of no added benefit.

A 3-arm randomized controlled trial conducted in Germany compared 3 different strategies for using EMG biofeedback-assisted pelvic floor muscle training.

Patients received EMG biofeedback-assisted pelvic muscle training in conjunction with conventional electrical stimulation, dynamic electrical stimulation, or no electrical stimulation.

Outcome measures included a quality of life questionnaire and VAS for degree of suffering.

All 3 groups had significant increases in quality of life over the 12-week training period. There were no significant differences found between the 3 groups.

Researchers who conducted a prospective randomized controlled trial in the United States found that the addition of biofeedback and pelvic floor electrical stimulation to a program of behavior therapy does not result in greater effectiveness than behavior therapy alone in patients with post-prostatectomy incontinence.

Patients had persistent incontinence for between 1 and 17 years.

Pelvic muscle exercises were taught using surface EMG electrodes placed over rectus abdominis and perianally or with an anal probe.

Incontinence decreased in patients receiving behavior therapy with or without additional biofeedback.
Early therapy with pelvic floor electrical stimulation and biofeedback might decrease the duration and degree of urinary incontinence after radical prostatectomy. Based on a randomized controlled trial conducted in Turkey, 80 patients who underwent radical prostatectomy were randomly assigned to receive pelvic floor muscle exercise instruction only, pelvic floor electrical stimulation only, or pelvic floor electrical stimulation and biofeedback. After 12 weeks, a significantly greater percentage of patients in the group receiving biofeedback had achieved continence. Leakage was also lower in that group, and quality of life measures were significantly greater. The value of biofeedback coupled with anal sphincter exercises, as part of the treatment regimen for fecal incontinence, remains unclear.

Based on a Cochrane systematic review, the review included 11 trials involving a total of 566 subjects. The trials assessed various methods of biofeedback (e.g., ultrasound, EMG, manometry); the feedback was delivered with the goal of providing the subjects with knowledge regarding their execution of specified tasks and/or rectal sensitivity retraining. The authors reported that further investigation is warranted.

Evidence for efficacy and safety of biofeedback for management of chronic constipation is inconclusive. Based on a Cochrane systematic review, randomized trials evaluating biofeedback and chronic idiopathic constipation in the adult population were considered for inclusion. The review included 17 studies with a total of 931 subjects. Various types of biofeedback were utilized with EMG as the most commonly used. Due to low or very low quality evidence and the wide variation in participants, interventions, selected outcome measures, duration of treatment, and follow-up post treatment, no firm conclusions can be drawn regarding the use of biofeedback for the management of chronic constipation. Additional high-quality research is warranted.

Researchers in China compared intensive with nonintensive biofeedback therapy for treatment of patients with constipation-related symptoms in a retrospective cohort study involving 63 patients. Biofeedback training involved training to relax the anal sphincter, enhance sensory perception, and improve rectoanal coordination to increase pushing effort based on intra-abdominal and intrarectal pressures. Intensive therapy was given once per day or every other day; nonintensive therapy was provided twice a week. Each patient received 16 training sessions. Outcome measures included symptoms of defecation difficulty such as hard stools, incomplete bowel movement, and low stool volume, graded on a 0 to 3 scale, as well as usage of medications and impact on social activities and work. There was a significant improvement in constipation-related symptoms after adaptive feedback in both groups. The intensive biofeedback therapy did not show better performance compared to nonintensive biofeedback therapy. The authors concluded that biofeedback training improved constipation and that nonintensive therapy was as effective as intensive therapy, despite the potential for the longer time required to complete 16 training sessions to have a negative impact on compliance.

Authors of an Australian randomized clinical study of the use of biofeedback with exercise for fecal incontinence compared 2 exercise regimes both using biofeedback. Patients were randomized to a standard clinical protocol consisting of sustained submaximal anal and pelvic floor exercises or to an alternative protocol of rapid squeeze plus sustained submaximal contractions. Both patient groups attained significant improvement in the severity of their fecal incontinence and quality of life, and no significant differences were found between groups. Biofeedback-assisted exercise was effective; however, more information about specific exercises to include is needed.

There is insufficient available evidence to determine if biofeedback is effective in the management of constipation. Based on a systematic review, the review included 5 trials comprising 252 subjects. Types of biofeedback examined in this review included manometric, EMG, and verbal; the feedback was delivered with the goal of providing the subjects with information regarding their performance or to provide rectal sensitivity retraining. The author reported that further investigation in trials with sound methodology is warranted.
Biofeedback, as part of a comprehensive treatment approach for constipation, was reported to be effective in reducing patient symptoms\(^{42}\)

- Based on a case series in Hong Kong
- 3 subjects participated in a multidisciplinary treatment regimen
  - Nursing – comprising patient education and use of a stool diary
  - Physical therapy
    - A multifaceted, individualized program that included biofeedback
    - The biofeedback program consisted of EMG and manometry
      - Initially the subject was seen every week (or every other week) for 3 months; then 1x/month for 3 months
  - Dietitian – individualized dietary plan was developed
- Results – comparing pre and post treatment (statistically significant)
  - Increased fiber intake
  - Reduced average straining effort
  - Reduced average straining time

A multifaceted treatment regimen comprising EMG biofeedback, neuromuscular electrical stimulation, and pelvic floor training/advice might decrease symptoms of bladder dysfunction in women with multiple sclerosis\(^{22}\)

- Based on a randomized (pilot) trial comprising 30 women with multiple sclerosis conducted in Ireland
- Subjects were randomized to one of three treatment groups for 9 weeks
  - Group 1
    - Pelvic floor training/advice
    - In conjunction with the patient education, the subjects were trained in pelvic floor muscle strengthening
  - Group 2
    - EMG biofeedback and pelvic floor training/advice
    - EMG was completed through a vaginal electrode
    - Individuals received visual and auditory feedback
  - Group 3
    - Neuromuscular electrical stimulation, EMG biofeedback, and pelvic floor training/advice
    - Neuromuscular electrical stimulation took place 1x/week (began with a duration of 5 minutes progressing to a total treatment time of 30 minutes)
- Results for primary outcome measure – statistically significant between group comparisons
  - 9 weeks – group 3 experienced significantly fewer urinary leakage episodes when compared to group 1
  - 16 weeks – group 2 experienced significantly fewer urinary leakage episodes when compared to group 1; group 3 experienced significantly fewer urinary leakage episodes when compared to group 1
  - 24 weeks – group 2 experienced significantly fewer urinary leakage episodes when compared to group 1; group 3 experienced significantly fewer urinary leakage episodes when compared to group 1
- Note: There were no statistically significant differences reported between groups 2 and 3 for this measure
- Comparing results for secondary outcome measures between groups 2 and 3
  - 24 hour pad test (measuring pad weight) – at 9 weeks, the difference between groups 2 and 3 was statistically significant in favor of group 3
  - Voided volume – at 9 weeks, the difference between groups 2 and 3 was statistically significant in favor of group 3

Pelvic floor exercises, with and without biofeedback, were found to be effective in reducing the occurrence of urinary incontinence in children and adolescents; however, further research with improved methodology is warranted (e.g., larger sample sizes, equal treatment durations) to assess if there is a clear advantage to the addition of biofeedback\(^{44}\)

- Based on a randomized controlled trial comprising 56 participants conducted in Brazil
- Participants were children or adolescents with a diagnosis of dysfunctional elimination syndrome (DES)
- Participants were randomized into one of two groups
  - Group 1 – 24 treatment sessions in total; 3 months’ duration
    - Drinking/voiding schedule
    - Postural reeducation (for toileting)
    - Voiding diaries
    - Proprioceptive and relaxation exercises for the pelvic floor
  - Group 2 – 16 treatment sessions in total; 2 months’ duration
- Same treatment as above
- Addition of sEMG biofeedback
- Results (including but not limited to)
  - There were no statistically significant differences detected when comparing the two treatment regimens
  - Both treatment arms had a significant decrease in the occurrence of urinary incontinence
  - Participants in group 2 experienced a significant decrease in post voiding residual (PVR) urine (assessed via ultrasound)

Biofeedback was shown to be an effective treatment for children with various types of bladder dysfunction\(^{86,87}\)

- Authors of a study in Turkey compared the effectiveness of biofeedback therapy in children with dysfunctional voiding (DV) and refractory overactive bladder (OAB)\(^{86}\)

  - 45 children had 3 months of biofeedback treatment
  - In patients with DV, significant improvements were found in multiple factors including urinary tract infections, urge incontinence, and fractionated voiding. In patients with OAB, significant improvements included decreased urinary tract infections, normalized frequency, and decreased urge incontinence
  - Overall, biofeedback treatment showed greater improvements in patients with DV compared to patients with OAB

- Authors of a randomized clinical trial in Iran studied the effects of animated biofeedback and pelvic floor muscle exercise in children with non-neuropathic underactive bladder(UB)\(^{87}\)

  - 50 children with UB, ages 5–16 years, were randomly divided into 2 groups. Group A received standard urotherapy (hydration, scheduled voiding, toilet training, and diet management), animated biofeedback, and pelvic floor muscle exercise. Group B received the same interventions as group A except animated biofeedback and pelvic floor muscle exercise
  - The addition of biofeedback and pelvic floor muscle exercise to a standard bladder program more effectively improved sensation of bladder fullness and contractility in children with UB

Biofeedback, implemented for reeducation of the pelvic floor, was reported to ameliorate symptoms in men with a diagnosis of chronic nonbacterial prostatitis and chronic pelvic pain syndrome (CPPS)\(^{45}\)

  - Based on a quasi-experimental study conducted in the Netherlands
  - The study comprised 33 men (2 ultimately dropped out)
  - Primary intervention – EMG biofeedback (pelvic floor reeducation) for a total of 6–8 treatment sessions
  - Results – comparing pre and post treatment (statistically significant)
    - There was an improvement in the average total Chronic Prostatitis Symptom Index (NIH-CPSI)
    - There was a decrease in the average value of the pelvic floor muscle tonus

Authors of a 2014 systematic review studied the role of biofeedback and soft tissue mobilization in middle-aged women with dyspareunia\(^{88}\)

  - Both biofeedback and soft tissue mobilization significantly reduced pain and improved sexual function
  - Gains were maintained for up to 12 months
  - Client preference and comfort as well as clinical expertise must be considered when selecting appropriate treatment for dyspareunia

• Disorders affecting the head and neck

Biofeedback, in conjunction with other therapeutic techniques, might assist in improving the symptoms of temporomandibular disorder\(^{46}\)

  - Based on a systematic review comprising 30 studies
  - The review investigated the usefulness of different physical therapy interventions for the treatment of temporomandibular disorder
  - 7 of 33 studies included in the review assessed the efficacy of relaxation training or biofeedback specifically
  - The authors call for further research in order to add more weight to the current body of evidence

Authors of a small randomized clinical trial (N = 12) in Japan who investigated the effects of biofeedback training on bruxism found a significant decrease in symptoms post 2 to 3 weeks of biofeedback training compared to a control group\(^{79}\)

Biofeedback EMG was reported to be superior to therapeutic exercise alone for the management of Bell’s palsy\(^{16}\)

  - Based on a case series in Italy
  - Time from onset of paralysis was an average of 16 days
- The subjects took part in one of two treatment protocols
  - Group 1
    - Comprising 28 subjects
    - Intervention consisted of therapeutic exercise (including “light friction type massage”)
    - Initially treatment took place 3-5x/week, 60 minutes each session; eventually frequency reduced to 1-2x/week in the clinic (subjects also had a home program)
  - Group 2
    - Comprising 37 subjects
    - Intervention consisted of EMG biofeedback (also included “light friction type massage”)
    - Initially treatment took place 3-5x/week, 60 minutes each session; eventually frequency reduced to 1-2x/week in the clinic (subjects also had a home program)
  - Group 1
    - Averaged 24 treatment sessions
  - Group 2
    - Averaged 17 treatment sessions
    - Experienced superior recovery when compared to group 1; this was evidenced through the greater resolution of motor impairments and reduced presence of synkinesis

Researchers who conducted a 2014 randomized clinical trial in Iran compared biofeedback therapy to conventional therapy (non-biofeedback) in patients with facial nerve dysfunction. 29 subjects who had facial nerve dysfunction (Bell’s palsy, tumor, or trauma) were divided into 2 groups. Group 1 was treated with biofeedback electromyography. Group 2 was treated with conventional therapy. All patients received 1 year of treatment
- Outcome measures included evaluation of facial grading scale before and after treatment and severity of synkinesia
- Both groups demonstrated improvements from baseline. Significant improvements were also demonstrated in the biofeedback group compared to the control group

Biofeedback EMG to reduce activity in bilateral upper trapezius muscles produced more favorable outcomes than active exercise or passive treatment for the management of work-related neck and shoulder pain in a randomized controlled trial conducted in China.
- 72 participants with neck and shoulder pain related to computer use were randomized into 1 of 3 interventions or a control group
- In the biofeedback group participants were instructed to use biofeedback daily on the upper trapezius muscles while performing their computer work
- The active exercise group participants were instructed in stretching and strengthening exercises of neck and shoulder muscles to be performed up to 20 minutes 4 times per day. The passive treatment group received interferential therapy and hot packs twice a week. The control group received an education booklet about office ergonomics only
- Outcome measures included pain (VAS), neck disability index (NDI), and muscle activity measured by surface EMG
- All 3 interventions improved NDI and EMG after 6 weeks of treatment. Biofeedback resulted in the greatest improvements in neck and shoulder muscle activation patterns during typing
- The biofeedback group showed more favorable outcomes in terms of reduced pain and better functional scores at 6 months follow up than active exercise or passive treatment

Abdominal muscle impairment
- Real-time ultrasound imaging was found to be an efficient visual feedback tool in a randomized trial in India comparing it to pressure biofeedback for training abdominal muscles in patients with chronic low back pain.
- 22 patients with chronic low back pain and weak transverse abdominis muscles were randomized into 2 groups for biofeedback training
- Patients were trained with the use of one of the augmented feedback approaches to preferentially activate the transverse abdominis using the abdominal drawing-in maneuver
- The number of trials and number of days required for learning the correct maneuver were significantly less for patients receiving real-time ultrasound imaging feedback than for patients receiving pressure feedback
- Real-time ultrasound might enhance skill acquisition by providing knowledge about performance as the patient performs the contraction, in keeping with motor learning principles
- Researchers In a study in the United States researchers measured changes in muscle thickness pre-/post-exercise and biofeedback in persons with low back pain.
Patients were equally divided into exercise without biofeedback or exercise with biofeedback groups. Exercise for both groups included 1 session of abdominal and back stabilization. Biofeedback included visual, auditory, and tactile components.

- No statistical differences were found between groups. Results demonstrated an increase in transverse abdominis preferential ratio; no thickness changes occurred in the lumbar multifidus muscles.

- Authors of a case study in the United States of the use of ultrasound imaging combined with running-form modifications found that lumbopelvic dysfunction in a postpartum runner was successfully treated with these techniques.

- The patient underwent dynamic lumbar stabilization training using ultrasound imaging biofeedback.

- Muscle thickness of transversus abdominis and internal oblique was measured pre- and post-intervention.

- The measurement properties of pressure biofeedback units have not been well established for the assessment of transversus abdominis muscle activity.

- Based on a systematic review, current evidence of reproducibility and validity of measurements taken from pressure biofeedback units is limited.

- Results of a clinimetric analysis of pressure biofeedback and transversus abdominis function in individuals with low back pain indicate that the pressure test is likely of minimal value to detect transversus abdominis activation.

- Successful completion on pressure biofeedback does not indicate high transversus abdominis activation, although unsuccessful completion might be more indicative of low transversus abdominis activation.

- **Athletic performance**

  - Biofeedback to improve athletic training and performance might include monitoring multiple parameters.
  
  - Feedback of heart rate variability (HRV), respiration rate (RR), muscle activation using EMG, skin temperature (ST), skin conductance (SC), and brain-wave activity frequency using EEG might be used to effect improvements in concentration, relaxation, reaction time, and skill performance.

  - The selection of optimal biofeedback modality depends on the personal psychophysiological characteristics of the athlete, as well as the specific features of the sport.

  - For example, EMG and galvanic skin response might be the most efficient modalities for a sport such as wrestling that involves tactile and proprioceptive sensitivity and intense emotion, whereas EEG might be more suitable for a sport that requires postural and breathing stability, such as rifle shooting.

  - Use of biofeedback to train changes in running technique has been found effective in well-trained runners trying to adjust their running mechanics.

  - Modifying running mechanics might improve performance by improving running economy as measured by metabolic cost.

  - Immediate improvements in running economy do not typically occur; it usually is necessary for runners to train with the new technique to learn to control new kinematics.

  - 18 trained runners participated in a Swedish study in which they received concurrent visual and auditory feedback of their step frequency and vertical displacement.

  - The runners were able to reduce their running metabolic cost by specified amounts by adjusting target levels of the 2 parameters being monitored by the biofeedback.

  - Biofeedback training might help to train stressed athletes to acquire control over their psychophysiological processes in order to perform better.

  - Based on a small randomized controlled trial conducted in India.

  - Thirty basketball players were randomly assigned to an experimental group that received heart rate variability training for 10 consecutive days, a placebo group that was shown motivational videos, or a control group that did not receive any intervention.

  - Response time, concentration, heart rate variability, respiration rate, and shooting differences were significant between groups.

  - Biofeedback training procedures and results often are different for athletes than for clinical patients. As compared with clinical patients, athletes are often more quickly successful with biofeedback.

  - Differences might include the purpose of the training and the characteristics of the training participant.

  - Athletes often do intensive training of several hours of daily sport practice that probably induces brain changes.

  - Biofeedback might enhance peak performance, but there are many other factors that also contribute to the success of the training, including motivation and intensity of training.
Athletes might learn “correct” methods via biofeedback, but it is essential to integrate the new awareness into their routine to obtain the changes that are the result of intensive practice.

- Muscle impairment/ultrasound as a biofeedback tool
  
  - Given the current body of evidence, solid conclusions cannot be drawn regarding the potential advantage of real-time ultrasound vs. standard biofeedback procedures during muscle reeducation.

  - Based on a systematic review
    - The review included 5 studies (3 randomized controlled trials, 1 case series, and 1 case study)
    - Studies meeting inclusion/exclusion criteria from 1980 to 2007 were included
    - In these studies, real time ultrasound was implemented as a form of visual biofeedback
    - The authors reported methodological concerns (e.g., small sample size) within the randomized controlled trials; heterogeneity among the trials prohibited meta-analysis

  - EMG biofeedback coupled with occupational therapy and functional electrical stimulation (FES) after stroke might lead to larger upper extremity functional gains than occupational therapy and FES alone.

  - Based on a randomized controlled trial in Brazil
    - 59 individuals with hemiplegia participated in the trial
    - Participants were randomized to one of two groups
      - Group 1 – EMG biofeedback coupled with occupational therapy and FES
        - 60-minute sessions, 2x/week
        - FES was administered over the wrist and elbow extensors
        - In an additional session per week, EMG biofeedback took place for 60 minutes
      - Group 2 – occupational therapy and FES
        - 60-minute sessions, 2x/week
        - FES was administered over the wrist and elbow extensors
    - Results – comparing the experimental and the control groups at 6 months’ time
      - Group 1 experienced significantly greater improvements in hand function
      - Group 1 experienced significantly greater improvements in wrist and elbow range of motion
      - There were no significant differences in the manual dexterity index or in the wrist/elbow spasticity measures

  - Addition of visual feedback during “push-up plus” exercise was more effective than the exercise alone for winged scapula
    
    - In a randomized controlled study of 12 individuals with winged scapula in South Korea, participants receiving visual feedback during the exercise showed significant differences in the activity of several muscles post exercise
    - Muscle activity in serratus anterior and upper trapezius was measured pre-and post-exercise by EMG
    - Visual feedback about scapula movement in the push-up position was provided via camera and PC monitor
    - Real-time visual feedback led subjects to continuously increase their contractions to prevent their scapulae from winging. This resulted in increased activity of the serratus anterior muscle and decreased activity of the upper trapezius muscle
    - Serratus anterior activity increased more in the experimental group than in the control group

  - Slow abdominal breathing plus EMG biofeedback training might be more effective than slow abdominal breathing alone for reducing blood pressure in women with prehypertension.

    - Based on a small randomized trial conducted in China
      - 22 women with prehypertension were randomized to experimental or control group
        - Experimental group – 10 sessions of slow abdominal breathing (6 cycles/minute) plus frontal EMG biofeedback training and home practice
        - Control group – 10 sessions of slow abdominal breathing (6 cycles/minute) and home practice
      - All women were postmenopausal
      - Slow abdominal breathing plus EMG biofeedback was associated with significantly greater reduction in blood pressure compared to slow abdominal breathing alone

  - HRV biofeedback might have beneficial effects on prehypertension
    
    - Based on a randomized controlled trial in China involving 43 individuals with prehypertension
      - Participants were assigned to one of three groups: HRV biofeedback, slow abdominal breathing, or control
      - Outcome measures included blood pressure, RR, baroreflex sensitivity, and galvanic skin response
- Prehypertensive individuals were able to lower their systolic blood pressure by an average of 13.8 mm Hg and their diastolic blood pressure by an average of 7.2 mm Hg with 10 sessions of HRV biofeedback.
- This blood-pressure-lowering effect lasted at least 3 months after treatment.
- Biofeedback has been used to effectively treat physiological components of psychological stress and anxiety\(^{(80)}\).
- Researchers who conducted a randomized clinical trial in Australia investigated the effects of biofeedback combined with relaxation, mindfulness, social support, and education (RMSSE) in 40 patients with MS. Both groups received RMSSE with one group receiving the additional treatment of biofeedback.
- Both groups demonstrated significant improvement in anxiety and depression. The biofeedback group also showed significant improvement in breathing rate and muscle tension compared to the control group.
- Biofeedback might help reduce foot pressure to a safe level in patients with diabetes and peripheral neuropathy\(^{(70)}\).
- Based on a study involving 21 patients with diabetic peripheral neuropathy conducted in Switzerland.
- Biofeedback on plantar pressure distribution was used to help the patients learn a new walking strategy in which the peak pressure under a previously defined at-risk zone was decreased to an acceptable range.
- Peak plantar pressure under at-risk zones decreased significantly without any increase in peak plantar pressure elsewhere.

* See Description, Indications of device/equipment, and Guidelines for use of device/equipment, above

<table>
<thead>
<tr>
<th>Problem</th>
<th>Goal</th>
<th>Intervention</th>
<th>Expected Progression</th>
<th>Home Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difficulty complying with weight-bearing status; gait deviations and impaired balance</td>
<td>Compliance with weight-bearing status</td>
<td>Biofeedback</td>
<td>Progress each unique patient as appropriate and indicated</td>
<td>Implement a home program to support the desired outcomes, as appropriate and indicated</td>
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<tr>
<td></td>
<td>Improved balance and lower limb function</td>
<td>EMG biofeedback has been used to assist in the management of spasticity;(^{(6)}) improvements in muscle tone might lead to improved gait patterns and balance reactions</td>
<td>Progression depends on underlying condition</td>
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<td>Force platform biofeedback might be used to address postural sway(^{(33,76)})</td>
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<td>(Please see Treatment summary, above)</td>
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<tr>
<td>Bowel or bladder dysfunction; chronic pelvic pain syndrome</td>
<td>Improve bowel or bladder symptoms; reduce pain</td>
<td>Biofeedback</td>
<td>Progress each unique patient as appropriate and indicated</td>
<td>Implement a home program to support the desired outcomes, as appropriate and indicated</td>
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<td></td>
<td></td>
<td>Might be implemented in an effort to facilitate and enhance contractions of the pelvic floor musculature(^{(59)})</td>
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<td>(Please see Treatment summary, above)</td>
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</table>
| Synkinesis (e.g., as in the case of Bell's palsy) | Improve patient symptoms | **Biofeedback**  
Biofeedback has been used to assist in the management of synkinesis (16-78)  
(Please see Treatment summary, above) | Progress each unique patient as appropriate and indicated | Implement a home program to support the desired outcomes, as appropriate and indicated |
<table>
<thead>
<tr>
<th>Muscle impairments (e.g., imbalance, atrophy, reduced strength; hemiplegia)</th>
<th>Normal or improved muscle function</th>
<th><strong>Biofeedback</strong></th>
<th>Progress each unique patient as appropriate and indicated</th>
<th>Implement a home program to support the desired outcomes, as appropriate and indicated</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>A pressure biofeedback unit might be used to assist with strengthening cervical musculature.(^{(60)})</td>
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<td></td>
<td>Cervical retraction exercises using pressure biofeedback were found to be better than cervical exercises alone in reducing pain and disability in patients with cervical spondylosis(^{(71)})</td>
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<td></td>
<td></td>
<td>EMG biofeedback might be used to facilitate selective increase or decrease in muscle activity to strengthen or achieve relaxation</td>
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</table>
| | | RUSI might be used to assess muscle contraction; this method provides visual feedback to both the clinician and patient.\(^{(7)}\) However, the authors of the literature review caution that more research is warranted to better establish the following:\(^{(7)}\)  
• The advantage of RUSI over other therapeutic techniques  
• Standardized protocols  
• Reliability of RUSI as a means to assess patient outcomes (please see Treatment summary, above) | | |

### Desired Outcomes/Outcome Measures

› Desired outcomes and outcome measures will be dependent upon underlying diagnosis and specific goals of intervention. Examples include:
• Compliance with weight-bearing status
• Improved bowel or bladder symptoms
  – Voiding diary
• Reduced pain
  – VAS
• Normal or improved muscle function
  – MMT
• Improved exercise tolerance
  – TUG test
• Improved balance
  – Berg Balance Scale

**Patient Education**

› The Association for Applied Psychophysiology and Biofeedback (AAPB), [https://www.aapb.org/i4a/pages/index.cfm?pageID=1](https://www.aapb.org/i4a/pages/index.cfm?pageID=1)

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### Coding Matrix

References are rated using the following codes, listed in order of strength:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>M</td>
<td>Published meta-analysis</td>
</tr>
<tr>
<td>SR</td>
<td>Published systematic or integrative literature review</td>
</tr>
<tr>
<td>RCT</td>
<td>Published research (randomized controlled trial)</td>
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<tr>
<td>R</td>
<td>Published research (non randomized controlled trial)</td>
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<tr>
<td>C</td>
<td>Case histories, case studies</td>
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<tr>
<td>G</td>
<td>Published guidelines</td>
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<tr>
<td>RV</td>
<td>Published review of the literature</td>
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<td>RU</td>
<td>Published research utilization report</td>
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<tr>
<td>QI</td>
<td>Published quality improvement report</td>
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<td>Published funded report</td>
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<td>Policies, procedures, protocols</td>
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<td>X</td>
<td>Practice exemplars, stories, opinions</td>
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<tr>
<td>GI</td>
<td>General or background information/texts/reports</td>
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<tr>
<td>U</td>
<td>Unpublished research, reviews, poster presentations or other such materials</td>
</tr>
<tr>
<td>CP</td>
<td>Conference proceedings, abstracts, presentation</td>
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### References


