THE USE OF VISUAL BIOFEEDBACK TO TREAT A PATIENT WITH PARAPLEGIA TO STRENGTHEN UPPER EXTREMITIES FOR IMPROVED WHEELCHAIR TRANSFERS

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The Use of Visual Biofeedback to Treat a Patient with Paraplegia to Strengthen Upper Extremities for Improved Wheelchair Transfers

PTY 768
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Abstract

Introduction: Visual biofeedback (BF) has been incorporated into Physical Therapy (PT) in several studies to improve balance, strength, and functional gains. The purpose of this case study is to track the progress of a patient with paraplegia using a visual BF system to improve wheelchair transfers along with traditional PT interventions.

Case Description: The patient is a 62 year old male seen in outpatient facility with a PT diagnosis post-op laminectomy with triceps weakness and a history of spinal cord injury with paraplegia. Therapy goals included increased ROM and strength of the left upper extremity and improved wheelchair transfers.

Outcomes: The QuickDASH improved significantly. The patient made gains in AROM and strength testing. Based on the BTE visual BF system, the patient made gains in wheelchair transfer simulation based on a 14.3% gain in concentric and eccentric force, 379.4% gain in work and 235.6% gain in power. Average force for isometric shoulder extension was 26.67 lbs initial session and 90.46 lbs at the final session. Percentage on target was 12% initially and 96% at the final session.

Discussion: Based on the outcome measures and subjective reports of improved functional use of the left UE, the BTE visual BF system may have contributed to the patient's gains.

Conclusion: Visual BF with traditional PT to improve strength, ROM and balance was used to assist the patient to make functional gains, particularly in wheelchair transfers. The patient benefitted from PT with increased function when compared to his post-op condition.

Keywords: Visual biofeedback, paraplegia, wheelchair transfers, BTE PrimusRS

Introduction

According to the American Spinal Injury Association (ASIA), describes the spinal cord as the body's method through which the body communicates motor and sensory information.[1] Spinal cord injury (SCI) potentially interrupts conduction of sensory and motor signals. To assist in a complete understanding of terms used throughout the following text, some definitions will be provided. *Paraplegia* refers to compromise of motor and/or sensory function in the thoracic, lumbar or sacral (but not cervical) segments of the spinal cord.[5] The level of injury determines the involvement of the trunk, legs and pelvic organs, however arm function is typically retained. *Complete injury* refers to a compromise of sensory and motor function in the lowest sacral segment.[1]

Shoulder pain is prevalent in reportedly 30% to 70% of individuals with paraplegia. Factors such as diagnosis, age, level of spinal cord injury and the time since the injury can influence the percentage.[2] Literature supports that the risk of shoulder pain and musculoskeletal disorders appear to increase as an individual with a spinal cord injury ages and occurs at a younger age when compared with an able-bodied person.[2] The high prevalence of shoulder pain could be due to the heavy reliance on the upper extremities (UE) for stability and mobility. In the chronic stages after a spinal cord injury, the UEs are exposed to overuse from activities of daily living as the shoulders is now a weight-bearing joint. Of all the subject characteristics studied in regards to the prevalence of shoulder pain and wheelchair users, age was the strongest associated with ongoing shoulder pain.[2] The subjects studied reported the most limitation was in wheelchair propulsion up ramps or inclines outdoors, loading the wheelchair into the car, lifting objects from an overhead shelf, and transferring to a car.[2]

Cervical degenerative disease, also known as cervical spondylosis, is a condition affecting the cervical spine and is prevalent in 85% of individuals over sixty years of age.[3] Common complications of cervical spondylosis include cervical myelopathy, radiculopathy, or myeloradiculopathy. The spinal cord can be compressed, resulting in clumsiness, loss of manual dexterity, motor weakness, sensory changes, and abnormal or pathological reflexes seen in upper or lower extremities.[3,4] Depending on the condition's degree of advancement as well as other factors, the decision may be made to manage the patient surgically. Regardless of the chosen surgical approach the aim is to relieve pressure off of the affected spinal cord or nerve roots, maintain or regain stability, and avoid potential kyphotic deformity.[4] Cervical nerve root palsy is a common side effect developed after cervical laminectomy surgery. This complication is believed to occur secondary to the post-surgical edema (swelling) of the spinal cord. C5 nerve root injury occurs reportedly in as many as 12.9% individuals after a laminectomy procedure.[5]

One aspect of the rehabilitative process to address the above mentioned issues following a SCI is often physical therapy (PT). Physical therapists often require adding creativity to therapy sessions for a number of reasons. A variety of interventions, depending on the diagnosis being treated, is required to keep the patient engaged in treatment to elicit full participation in order to attain the prescribed goals in therapy. There is always a risk of therapy sessions becoming repetitive, which translates into unskilled therapy. If a therapist is unable to justify skilled therapy, there may be implications for no reimbursement from the respective insurance company. Therapists must provide skilled therapy through a combination of traditional treatment with newer treatment modalities in order to keep the patient interested and produce favorable results for goal attainment. The world of PT is

constantly changing with newly emerging research advocating use of a certain technology, treatment method, and other areas.

Physical therapists must take advantage of the newest technology available, basing use on traditional, established theory. One such example is the use of biofeedback (BF) as an intervention. BF literally means "life" and "returning knowledge to origin."[6] This implies the phenomenon of returning the biological knowledge back to the origin in order to create understanding and control that knowledge. BF has also been described as the process of learning and controlling the physiological functions of the body, whether it is voluntary or involuntary.[6] Collectively, BF can be defined as a group of therapeutic procedures through the use of electronic instruments to measure, process and provide feedback to patients. The feedback delivered can be in auditory and/or visual form. The ultimate goal is to develop greater awareness of voluntary control over their physiological processes that are otherwise compromised. It also is utilized as an adjunct to conventional PT practices to enhance rehabilitation, thus BF used alone would be unsuccessful.[6]

BF can be used for muscle relaxation as well as strengthening of muscles. This form of intervention has been utilized with individuals who have sustained SCIs to improve strength and active range of motion (ROM) of extremities. The mechanism and effectiveness of BF is currently unknown, although it is suspected to work via the growth of new pathways or activation of existing cerebral pathways.[6] Research suggests feedback signals activate dormant or underutilized synapses in existing motor commands. There is a possible role of the repetitive and concentrated practice performed in BF that contributes to brain plasticity.[6]

PT goals, particularly in the outpatient setting, are functionally oriented. The strengthening, stretching, and other interventions utilized should all translate to a functional

meaning for the patient. In regards to BF, the intervention (along with traditional therapy) may be utilized to simulate a movement required for work-related task if PT goals are to return to work. BF can be used to assess a person's baseline, for example, hand grip strength, and continue therapy related to such motions to increase the strength and ROM of the intrinsic and extrinsic muscles. Although there are several forms of BF (auditory, sensory, etc) the focus of the discussion will be visual biofeedback in relation to a particular computerized system.

BF has been the focus of several studies. Some areas of focus are in falls prevention, particularly in the elderly. One study compared the outcomes in elderly patients in groups that received only traditional physical training (n=12) and another group receiving the same traditional physical training and computer feedback (n=15). The results of the study show a marked increase in training results and performance in dynamic balance tests including the Berg Balance Test in comparison to the group receiving traditional therapy. Both groups improved greatly in outcomes and there was an improvement in the group receiving the additional computer feedback training. Although the study did not present significant benefits to computer feedback, the authors speculate the little improvement that did occur compared to the traditional group can be owed to the idea receiving computer feedback provided a sense of encouragement to the patient, thus translating in to increased compliance/participation with treatments. The authors report that when using a game or visual feedback system, it encourages competition within a patient and between patients, which increases compliance.[7]

A systematic review conducted by Zijlstra et al in 2010 studied the effectiveness of BF-based training through for balance and mobility in the elderly. The authors mention how

there is research regarding the effectiveness of BF-based training in improving movement performance for stroke rehabilitation. There are implications for relevance of the 27 studies evaluated to support independent function in older adults; however, there is a deficit of thorough studies investigating the effectiveness of BF-based interventions in general. Some limiting factors are thee co-morbidities associated with aging such as disabling health conditions, musculoskeletal impairments, cardiovascular issues , and decreased sensory function, and cognitive impairments. Some possible factors affecting feasibility of BF interventions are adherence to programs, adverse incidents, omission of subjects with co-morbidity, attention load and processing sensory information from BF signals, and subject's experience and motivation during training. The authors also found that while using visual BF for balance training in older post-stroke adults, the subjects report that they enjoyed the BF treatment because they were fully aware of what was required of them to reach the goal and were able to interpret the results themselves. Visual BF was especially useful for those patients with severe communication deficits. These subjects also reportedly understood the idea of training more successfully when compared to conventional training methods. The study systematically analyzed the results of several studies to report that there is in fact a benefit to adding BF to traditional therapy when compared to outcomes of a group receiving traditional therapy. The authors also point out how the majority of these studies provide information on short term outcomes and fail to follow up with the subjects to assess carry over and long terms effects of treatments. Some suggestions for future studies as suggested by the authors were to focus therapy utilizing BF systems in such a way that the intervention simulates everyday life tasks and challenges, which would be beneficial for carry over long term.[8]

The particular visual BF apparatus used in this case report is called the Baltimore Therapeutic Equipment (BTE) PrimusRS. Much research has been done using this computerized system in the physical and occupational therapy field. It is used for multi-joint testing, orthopedic rehab, neuromuscular reeducation, athletic training of the upper and lower extremities as well as the core.[9] The system can be used to evaluate baseline, rehabilitate, and track progress throughout therapy, with isotonic, isometric, isokinetic and continuous passive motion resistance modes. With adjustable resistance modes, heights, and a variety of attachments, the BTE is designed to simulate nearly any functional task or activity of daily living to assist in return to function and improvement with objective measures.

The patient discussed in the following case study experienced post-cervical (C6-C7) laminectomy residual weakness of his left upper extremity. Yet another factor to consider was that the patient was wheelchair bound from a previous un-related condition. How the patient sustained the spinal cord injury was not discussed. This issue was irrelevant to the current condition and was sustained several years prior. However, the fact that the patient was wheelchair bound secondary to paraplegia played a large role in modifying physical therapy treatment positions as well as the goals for (PT) treatment.

The purpose of this study is to track the progress of a patient with paraplegia using a visual BF system to improve his wheelchair transfer ability along with traditional physical therapy interventions (strengthening, balance techniques, functional tasks, etc).

The research question of following case study is: What are the improvements in outcomes after use of a visual BF system to improve wheelchair transfers in a patient with paraplegia? This case report was approved by the Institutional Review Board at The Sage Colleges in Troy, NY.

Case Description

The patient in this case report is a 62 year old male. The patient had an elective C7 laminectomy approximately one month prior to being seen at the outpatient facility. The patient was referred to outpatient PT one month after the surgery by his physician secondary to difficulty with wheelchair transfers and overhead tasks, particularly with the left upper extremity use. The patient participated in acute in-patient rehab PT, occupational therapy (OT) and received home PT post-surgery with reported standard interventions to return to functional status.

The patient's past medical history (PMH) includes the following: T11 ASIA A spinal cord injury in 1971 with neurogenic bladder and bowel, obstructive sleep apnea, GERD, diabetes mellitus 2, hyperlipidemia, osteoarthritis. The spinal cord injury was acquired approximately 40 years prior, resulting in paraplegia. The mechanism of injury was not reported. The patient reported being generally independent with most activities of daily living (ADLs) prior to the most recent surgery. He reported requiring only some distant supervision from caregivers, mainly his wife, in transferring. Since the elective surgical procedure, the patient reported difficultly with some ADLs and wheelchair transfer as well as overhead tasks (reaching for objects above, etc). The patient notes that transferring to and from bed as well as toilet transfers are particularly the most difficult and require distant supervision from a caregiver for safety. The patient denied any report of falls in his history.

The patient reports actively participating in aerobic exercise using adaptive equipment at a local gym. He reports having some instruction from the gym owner, who is also a person with a disability. The patient, however, sought PT to gain back strength and

range of motion as well as to receive accurate instruction on which muscle groups to focus on to ultimately increase independence with wheelchair transfers.

The patient currently is working full time as a co-owner of a family business. The nature of his work requires full use of bilateral arms and fine motor skills (use of digits/fingers).

Examination

History: The patient reported only receiving acute rehabilitation and few visits of home PT post-surgery. The patient's level of function prior to surgery/radiculopathy was independent with transfers with full use of bilateral upper extremities (UE). He reported a feeling of "stiffness" in the neck. A scale of 0 to 10 was used; 0 being no pain at all and 10 being the worst pain ever experienced, as described by the Numeric Pain Rating Scale (NPRS).[10] The patient reported at rest pain would be 1/10 and with activity would be 2/10. Functional limitations included transferring independently and completing overhead activities.

Systems Review:

Cardiovascular/Pulmonary: Upon initial exam the patient's blood pressure was 120/68 mmHg. The patient's vitals were not a concern and were within normal limits upon the initial evaluation. He reported performing regular aerobic activity using an arm bike (arm ergometer) independently at a local adaptive gym.

Sensory: The patient was tested for light touch in the seated position (in his wheelchair). The examiner used the sharp end of a reflex hammer to conduct the test. Each dermatome was grossly tested of bilateral upper extremities with the patient's eyes closed. Sensation to light touch was grossly intact on bilateral upper extremities. The patient's lower

extremities were not tested due to the nature of the patient's paraplegic condition/complete spinal cord injury. The patient reported from previous knowledge that sensation is absent from the mid-abdomen and down.

Observation/posture: The patient presented with rounded shoulders with the left shoulder elevated compared to the right appearing as slight lateral trunk flexion to the right. The patient had abdominal obesity and sat with forward head posture. The patient presented with a slight postero-lateral rib hump on the left approximately at the level of the 10^{th} or 11^{th} rib. The patient reported the left postero-lateral aspect of the trunk felt as if it had increased pressure on the wheelchair back occasionally, requiring him to remove part of the wheelchair handles that were originally meant for positioning in order to sit more comfortably.

Alertness/orientation: The patient had no barriers to learning/communication. The patient only had a possible physical barrier due to paraplegia and being wheelchair bound. The patient had a good understanding of his condition and was able to communicate questions and concerns coherently with the therapists and all others involved in his care. He was able to operate his vehicle independently to drive to the outpatient clinic with the use of built-in vehicle adaptive equipment.

Tests and Measures:

QuickDASH: The Quick Disability of the Arm Shoulder and Hand (QDASH) was used as one outcome measure to track progress in therapy. The QuickDASH is an 11-item questionnaire dealing with symptoms and impairments of the upper extremities. The summative score is based on a 100% scale, where a higher score indicates more disability. The QDASH is found to be a reliable and valid outcome measure. Test-retest reliability is found to be 0.90 for the QuickDASH.[11,12] The minimal clinically important difference

(MCID) is a change in 8.0 points.[11,12] The QuickDASH has demonstrated good reliability, validity, and responsiveness when used for individuals with upper extremity impairments.[12] The outcome measure was administered upon initial evaluation, re-evaluation, and upon anticipated discharge date from outpatient PT. The patient's initial score on the QDASH was 47.

Numeric Pain Rating Scale (NPRS): It is typical for the clinician to ask the patient to rate his or her pain on a scale of 0 to 10, with 0 being no pain at all and 10 being the worst imaginable pain. The test-retest reliability for the NPRS is found to be 0.74. The minimal clinical important difference for the NPRS is 1.1.[12] The patient reported pain intensity at rest as a 1/10 and pain with activity as a 2/10 in the left upper extremity.

Integumentary: At the time of evaluation, there was no presence of sores or wounds. The patient, however, verbally reported a history of occasional pressure wounds on his buttock/thigh region. Reuler and Cooney found that an individual seated in a wheelchair had the greatest pressure directly under and just lateral to the ischial tuberosities, making these areas to most at-risk for pressure sores.[13] Wound assessment/wound checks are of prime importance in patients with a lack of sensation, particularly wheelchair-bound patients.[13]

Musculoskeletal System: Girth measurements were taken six inches above the lateral humeral epicondyle of both upper extremities. This was to observe and compare any change in muscle bulk before and after PT. A standard tape measure was used to take measurements on both upper extremities. The following are the obtained results: Right: 16 inches, Left: 15 inches. The patient was unable to actively extend the third digit of the left upper extremity. However, there was no limitation in passive ROM of the third digit. The patient also reports occasional numbness and "tingling" sensation from the left shoulder to the fingertip of the

third digit on the left hand. The patient was asked to perform a "wheelchair push up" while gripping both handles of the wheelchair. The patient was able to do one wheelchair push up with his weight deviated to the right side to ease left side upper extremity load. It was apparent that there was an avoidance of weight bearing on the left UE. *Range of Motion (ROM):* The patient's bilateral UE ROM was assessed in the seated position using a standard goniometer. No modifications were required to complete ROM testing. One study reports good intertester reliability for goniometric upper extremity ROM testing (r=.86).[14] Refer to Table 1 for ROM measurements obtained upon initial evaluation. *Manual Muscle Testing (MMT):* The patient's bilateral upper extremity strength was assessed through MMT.[14,15] A systematic review conducted by Cuthbert and Goodheart supports that interexaminer reliability ranges from 82% to 97% and 96% to 98% for test-retest reliability, depending on the study. The literature review supports that there is evidence for good reliability and validity in the use of MMT for patients with neuromuscular dysfunction.[16] The patient was seated in his wheelchair for all testing. No modifications were required due to the patient being wheelchair bound. Refer to Table 2 for values obtained for MMT testing of the right and left upper extremities.

Neuromuscular system: The patient's upper extremity was tested for the integrity of the biceps reflex. Reflexes are graded on a scale of 0, 1+, 2+, 3+, and 4+. A score of 2+ indicates normal reflex.[15] A score under 2+ indicates hyporeflexia and above 2+ indicates hyperreflexia.[15] The results for the biceps reflex testing were as such, left: 1+, right: 2+. Reflex testing of the lower extremities was not indicated due to the patient's condition of paraplegia secondary to complete spinal cord injury

Baseline testing of BTE visual biofeedback system: Isotonic left shoulder extension: Refer to Figure 1 for patient positioning for isotonic left shoulder extension. Refer to Table 3 for initial and final isotonic left shoulder extension values. Isometric left shoulder extension: Refer to Figure 2 for patient positioning for isometric shoulder/elbow extension. Refer to Figure 3 and Figure 4 for values obtained for average force per session and percentage of target. Both figures display the progression over time from initial to final treatment session.

Evaluation

The patient had impairments of the left UE (atrophy, loss of ROM, decreased ROM) affecting his ability to functionally transfer to and from the wheelchair and complete basic overhead activity secondary to the elective surgical procedure.

Diagnosis

Pattern 4I: Impaired joint mobility, motor function, muscle performance, and range of motion associated with bony or soft tissue surgery.[17]

Pattern 5H: Impaired motor function, peripheral nerve integrity, and sensory integrity associated with non-progressive disorders of the spinal cord.[17]

Prognosis

The patient's prognosis was marked as 'excellent' upon initial evaluation. This prognosis was based on several factors including patient motivation, time allowed for therapy, co-morbidities, and baseline status.

It was projected that the patient was to attend outpatient therapy 2 times a week for 30 minutes each for a total of 12 weeks. The patient was to be discharged from the outpatient facility based on his ability to transfer independently and when he presented with increased strength and ROM of UE, with an emphasis on the left UE.

Goals and Plan of Care

The short term goal (STG) was the following: The patient will be independent with home exercise program (HEP) by the end of 2 weeks. Long term goals (LTG) included the following: 1) The patient will be able to independently transfer from wheelchair to mat with bilateral UEs by the end of 12 weeks, 2) The patient will increase triceps strength to 4/5 to aid lifting objects overhead by the end of 12 weeks. Plan of Care (POC)*:* The patient will receive PT 2 times a week for 4-12 weeks. Interventions included the following: home exercise program (HEP), neuromuscular re-education, progressive resistive exercise (PRE), stretching, functional electrical stimulation (FES) to left triceps, patient education, and visual biofeedback to simulate wheelchair transfers.

Interventions

The initial evaluation determined a plan of care that required the patient to attend PT sessions two times a week for 4-12 weeks. The following is a description of the interventions carried out throughout therapy. It may be of importance to note that the patient was not seen by the same therapist each session, which is typical of this particular outpatient setting. All interventions were performed in the seated position (the patient was seated in his wheelchair) unless otherwise noted.

Week 1:

Modalities: Upon initial evaluation, the patient mentioned to the therapist that he owned a personal functional electrical stimulation (Empi Focus Neuromuscular Stimulator) home unit from previous therapy treatments for his weakened triceps function on the left UE. The patient had not been using the FES unit consistently at home after being prescribed the unit. The patient

was asked to bring in the home unit on the first visit in order to review appropriate pad placement and settings. Two leads were applied to the left triceps (one proximally and one distally along the muscle) and with the following settings: 10 seconds on, 20 seconds off. The patient was educated and asked to demonstrate pad placement using the FES unit with each session until the treating therapist felt that the patient was completely independent in using the unit safely and correctly.

Neuromuscular re-education: The patient was seated in his wheelchair while performing the following exercises using an orange Theraband. The patient held a Theraband secured to the wall in both hands to perform triceps extension with shoulder flexion at 90º, forearm pronated (30 reps), and forearm supinated (30 reps). Wrist extension exercises were given using the green Theraband (30 reps). Shoulder pullouts were performed using a green Theraband at 90º shoulder flexion (30 reps) and 120º shoulder flexion (30 reps).

Therapeutic Exercise: Using the Cybex FT 360 gym trainer, the patient performed single arm (left) retraction with 1 plate (30 reps) which was progressed to 2 plates upon the last session based on the patient report that "one plate was too easy." Triceps extension was performed with the shoulder in neutral using 1 plate (40 reps). Later in the week, bilateral latissmus dorsi pull down exercises (better known as lat pull down) were added and was progressed to 3 plates, (30 reps x 3 sets). Horizontal abduction with triceps extension on the left UE was added with 1 plate (20 reps) with minimal support required from the right, non-involved UE. Biceps curls were performed as well using 4 plates (40 reps x 2 sets).

Week 2:

Modalities: The patient used the FES unit at each subsequent visit and did not require any more instruction on pad placement or use.

Neuromuscular re-education: Wrist flexion and extension exercises were added using the green Theraband (20 reps x 2 sets). Left elbow extension exercises were added with increased resistance initially with the purple Theraband (highest resistance). The patient was asked to hold the position of full elbow extension for 3 seconds and then release. The patient reported the purple Theraband was too difficult and was then given the green Theraband to complete the exercises. The patient continued the shoulder pullout exercises at 90º and 120º of shoulder flexion.

Therapeutic Exercise: Using the Cybex FT 360, the following exercises were performed. Bilateral UE rowing at 3 plates (15 reps x 3 sets), bilateral shoulder extension, lat pull down, horizontal abduction with triceps extension, scapular depression, bicep curls, triceps extension and cross over retract.

Week 3:

Neuromuscular re-education: The patient performed a baseline evaluation of the BTE visual biofeedback session for isometric scapular depression and isotonic shoulder/elbow extension for a total of 16 minutes (8 minutes each). Refer to Figure 1 and Figure 2 for patient positioning. The patient was asked to continue wrist extension and flexion exercises with the Theraband (10 reps x 3 sets).

Therapeutic Exercise: The patient continued strengthening exercises using the FT 360. Crossover retract, bilateral shoulder extension, horizontal abduction, scapular depression, shoulder extension exercises were continued with the same number of reps and sets to maintain strength. A posterior capsule stretch, levator scapulae stretch, and forward and backward shoulder circles were added as well. The patient was due for an "MD update" re-evaluation in the third week, as per clinic policy as well as for insurance purposes. The re-evaluation process

consisted of administering the outcome measure (QDASH) to compare scores at evaluation to the present values, active range of motion values, strength testing, progress toward short term goals, long term goals, and overall assessment of progress. The re-evaluation was meant to either change the plan of care, or discharge the patient based on either meeting the short and long term goals or failure to meet objective, functional gains, warranting referral back to the referring physician. Based on the measures, a plan was made to continue therapy as per the original plan of care.

Week 4:

Neuromuscular re-education: BTE visual BF was performed with the same set up for isometric scapular depression and isotonic shoulder/elbow extension. The patient was asked to perform PNF patterns using the left (involved) upper extremity using the FT 360. The patient performed D1/D2 flexion and extension movements (10 reps x 3 sets). The patient was also given scapular clocks at 90º of shoulder flexion (10 reps x 2 sets) and 90º of shoulder abduction (10 reps x 2 sets) with a weighted ball held in the hand. The weight of the ball was approximately 3 pounds.

Therapeutic Exercise: The patient continued exercises using the FT 360 to maintain strength. The patient performed cross over retract, bilateral shoulder extension, horizontal abduction using the left upper extremity, and bilateral scapular depression. The patient also performed levator scapula stretch on the left side as well as ulnar nerve glides. The ulnar nerve glides were added because the patient continued to complain of a discomfort of pain/tingling sensation starting from the left lateral neck down to the 3rd digit.

Week 5:

Neuromuscular re-education: Visual BF was conducted in the same manner as before. The patient's goal was to beat the previous score for the isotonic shoulder/elbow extension. The patient was also encouraged to stay within the range or above the target with the isometric scapular depression. The time (16 minutes total, 8 minutes each) remained the same. The patient also performed scapular clocks with a weighted ball held in hand at 90º of flex and then again at 90º of shoulder abduction.

Therapeutic exercise: Bilateral shoulder extension, bilateral cross over retract, bilateral scapular depression, left horizontal abduction was performed as the previous week. An additional exercise of left shoulder adduction was performed as well using the FT 360 (10 reps x 3 sets).

Therapeutic Dynamic Activities: The patient was placed next to an adjustable plinth in height in order to simulate a wheelchair to bed transfer. Initially, the patient was asked to transfer leading with the right (right side was closest to the bed). The patient then was asked to perform a transfer from bed to wheelchair while leading with the left (involved side). The last visit of the last week, after the assessment that the patient was capable of safely transferring independently while leading with the right side from wheelchair to bed, the patient was asked to perform transfers as he would at home while transferring to and from the wheelchair while leading with the left involved side. A re-evaluation was performed on the patient in week 5 in order to track progress in therapy.

Week 6:

Neuromuscular re-education: The focus of neuromuscular re-education for the remainder of therapy was to continue the BTE visual biofeedback isometric scapular depression on the left upper extremity and isotonic shoulder/elbow extension of the left upper extremity as well. After

practicing transferring leading with the left side from wheelchair to bed multiple times, the patient was asked to remain seated on the plinth to practice balance and further dynamic activities in the unsupported seated position. While seated on the plinth, without support, the patient was asked to perform "capital letter alphabet letters" while holding a weighted ball with both hands. The weight of the ball was approximately 6 pounds. The patient was asked to complete two full alphabets with short rest breaks as needed between sets. After this activity, the patient was asked to perform a reaching task. The therapist was standing approximately 3 feet directly in front of the patient. A ball held in the therapist's hand was placed in front and on both left and right sides of the patient as the patient was instructed to reach for the ball and simply touch it with his fingertips and return to the original seated position. Toward the end of the week, an overhead reaching component was added. The patient was seated without support on the plinth and asked to simply touch the ball placed over his head with his fingertips and return to original position. The last visit of the week another task was added. The patient, while seated unsupported on the plinth with both arms fully extended to his sides with palms flat on the table, each approximately one foot away from his hips, was asked to laterally flex his trunk while bending his elbows in order to have his elbow touch the plinth as far as possible.

Wound assessment: The patient complained of an uncomfortable sensation on the left lateral trunk approximately at the level of the 8^{th}-9^{th} rib. A small wound was observed at the apex of what appeared to be a rib hump on the left side. The wound was measured at 1.5 cm in diameter and described as a yellow-brown color and redness was observed along the edges. Some scabbing was present. The patient reports hypersensitivity to light touch at the exact wound site. The patient was then instructed to closely watch the potential sore at home (via caregiver) and inform the overseeing physician about the potential sore. The patient was also

instructed to keep a rolled towel at the lumbar lordosis in order to relieve pressure off of the wound site form constant contact with the wheelchair back. The patient was also educated on the importance of postural correction through the lumbar roll use. Over the next 2 visits, the wound decreased in size and the color decreased in redness, indicating decreased irritation.

Week 7:

Neuromuscular re-education: the BTE visual biofeedback for isometric scapular depression of the left upper extremity and isotonic shoulder/elbow extension was performed as was in the previous weeks.

Therapeutic Dynamic Activities: The focus of therapeutic dynamic activity was to practice sitting balance (unsupported) while performing reaching tasks and weight shifting on an unsteady surface. The patient was asked to sit unsupported on the plinth and a dynadisc (unsteady surface) was placed at either side of the patient (approximately 1 foot away from each hip). The patient was then asked to weight shift with lateral trunk flexion and elbow flexion such that the elbow comes down to the table as far as possible. The patient was also asked to perform scapular depression bilaterally as if to push him up off the table while the dynadisc remained at his sides.

Patient education: Although patient education was not reserved solely for the last week of therapy, it was emphasized in the last week, particularly in anticipation of the upcoming discharge. The patient mentioned throughout treatment that the firmness of his bed appeared to inhibit this ability to transfer "smoothly" from his wheelchair to the bed. He mentioned that upon eventually successfully transferring to the bed, he felt as if he was "sinking" into the bed, making readjusting his position very difficult and requiring a great deal of energy. He also mentioned that he and his wife were in the process of searching for a new mattress. The patient was

educated on the importance of a firm mattress to aid in ease of transfers as well as enhancing energy conservation for positional readjustment. The patient also mentioned that his wife was his primary caregiver. The patient was requested to have his wife accompany him to at least one therapy session in order to educate her in how she can assist in transfers using proper body biomechanics. He denied the need to do so, as she was unable to due to personal reasons as well as his desire to become more independent and lessen the need for her help for activities of daily living. This issue was thus not further pursued.

The patient was yet again re-evaluated and the decision was made to discharge the patient based on his ability to achieve the short and long term goals as well as the significant improvement on the outcome measure, the QuickDASH. The patient was given a yellow Theraband to practice further exercises independently at home. The patient was also educated on exercises to maintain the strength and ROM gained in therapy at the gym he attended independently.

Outcomes

Subjectively, the patient reported feeling that he has made significant progress throughout therapy, particularly with transfers to and from his wheelchair at home. The patient reported looking into purchasing a firmer bed, as discussed in an earlier therapy session, to help improve his transfers. He also reported consistently attending gym sessions independently in order to maintain the gains made in therapy. Based on the QuickDASH outcome measure, the patient scored 27% compared to the initial evaluation score of 47%. This is significantly beyond than the minimal clinical important difference of 8 percentage points, meaning the self-reported measure indicates greater usage of the left involved upper extremity functionally.[12] The patient reported an overall improvement in function based upon the functional outcome measure. Comparing the

AROM of the left UE elbow extension, the initial evaluation was measured as -10° (or a lack of 10 degrees of elbow extension). On the date of discharge, the patient's left UE MMT improved for all muscles except for shoulder extension. Refer to Table 4 for values for strength comparing initial evaluation and date of discharge.

The patient displayed and reported independence with the prescribed home exercise program. He reported performing the exercises "regularly" and incorporated them into his independent exercise regime at the gym. The patient reported gaining independence in transferring to and from his wheelchair to the bed with decreased need for his wife to be present for physical support while transferring. He felt more confident in transferring, particularly when transferring leading with the left involved side. According to the BTE visual BF system, the patient made gains in strength and power while performing the wheelchair transfer. This is apparent especially since the patient had reached a plateau while performing the left upper extremity isometric shoulder/elbow extension. The target for isometric extension was increased on one session to 80.0 pounds of force and again a few weeks later to 90.0 pounds of force. The decision to increase the target poundage was based on the observation that the patient was consistently reaching the target while performing the task, making the task "too easy." Thus, the target poundage was increased. Despite making the target poundage 90.0 pounds, the patient was almost consistently able to remain above the target, which is apparent according to the graph representing the average force performed by the patient and the percent on target. Refer to Figures 3 and 4 for progression and results of isometric shoulder extension average force per session and percentage on target, respectively.

In regards to the isotonic shoulder extension (concentric and eccentric), when comparing the initial baseline values for force, work, and power to the last performance on the BTE, the

patient also made improvement as well. Refer to Table 3 below for overall progress and results of isotonic shoulder extension.

Discussion

Physical therapists are often posed with the challenge of coming up with creative methods to incorporate a variety of interventions in therapy using the facility's available technology to maximize benefits of therapy, translating to functional gains for the patient. The specific goals for the particular patient described in the case study were aimed at improving wheelchair transfers. The patient had a pre-existing condition of paraplegia and had adapted well to transferring in and out of his wheelchair. However, after undergoing C6-C7 laminectomy secondary to cervical radiculopathy, the patient found transferring difficult, particularly after left triceps weakness post-operation. The patient's goals were to increase strength and ROM to improve transferring and reduce and/or eliminate the need for his sole caregiver, his wife, to be present when transferring in and out of the wheelchair. Manual wheelchair users are commonly diagnosed with nerve damage of the UEs, particularly Carpal Tunnel Syndrome and ulnar nerve injury with and incidence of 49% and 63%, respectively. UE injuries can have significant consequences due to the heavy reliance on their arms for mobility, transfers, and most activities of daily living. UE pain in this population has been associated with lower quality of life and increased dependence on caregivers.[18]

The initial evaluation determined a plan of care that required the patient to attend PT sessions two times a week for 4-12 weeks. The reasoning for the wide range of the anticipated weeks of participation was an insurance authorization issue. The nature of the patient's insurance required pre-authorization of the number of visits upon initial evaluation. Typically, the maximum number of visits is requested in order to avoid extensive paperwork in the event that

the patient will require more than the anticipated 6 weeks. The patient was able to continue therapy beyond the anticipated 6 weeks without requiring a new physician's prescription as well as the ability to avoid the lengthy pre-authorization process typical of the patient's insurance carrier. The patient performed interventions to strengthen his upper extremities using the FT360 as well as participating in neuromuscular re-education through the use of Therabands and weighted balls in certain shoulder flexed and abducted positions. The BTE visual BF system was utilized to incorporate motivation as a part of therapy to reach a target to simulate wheelchair transfers through isotonic shoulder/elbow extension as well as isometric scapular depression on the involved left upper extremity. Hagedorn and Holm used visual BF in balance training with elderly subjects. The researchers report that when using a game or visual feedback system, it encourages competition within a patient and between patients, which increases compliance. Like the subjects in Hagedorn and Holm's study, the patient in this case reported that the motivation behind doing better in therapy was to reach the target on the screen.[7]

Among the variety of uses, BF is used in rehabilitation for spinal cord injuries for improvement in active range of motion and function of the extremities.[6] Literature supports that biofeedback should be delivered while performing functionally related dynamic activity in order to optimize motor function improvement.[19] Much of the literature regarding the use of visual BF through use of the BTE is devoted to functional grip strengthening and for use with lower extremities (knee and hip strengthening). Some studies, such as the research conducted by Shechtman et al. in 2003 tested the reliability and validity of the BTE Primus grip tool as well as comparing the strength scores taken by the BTE vs. the Jamar dynamometer. The BTE Primus grip tool was found to be reliable (r=0.97 to 0.98) and valid (r=0.95 to 0.96) . No significant differences were found between strength scores obtained by the standard Jamar dynamometer

and the BTE grip tool.[20] Another study conducted in a similar manner aimed to find the effect of body position on strength. One group (n=13) of participants was wheelchair users while the control group (n=13) was participants without disabilities. The findings suggest that the BTE Primus may be used to assess grip and wrist flexion strength validity and reliability for both wheelchair users and persons without disabilities.[21] In an effort to test the reliability of the BTE during functional task simulation, Palmer and Uhl had healthy individuals (n=18) perform power tests involving a chop, lift and endurance activity. The study found that the above mentions protocol generated reliable data and can be used as a dynamic trunk test to simulate functional tasks requiring dynamic trunk control.[22]

The visual BF was continued until the end of therapy while the balance and transfer activities were progressed. Determining progression of balance and dynamic activities was through decreasing the amount of supervision required while transferring as well as making the surface on which dynamic activities were performed more unstable. The progress in therapy was apparent from the significant improvement on the self-report outcome measure, the QuickDASH, as well as the increase in AROM and strength measures.

Other interventions included wound assessment and skin checks. Being wheelchair bound is one of the common characteristics found in a study attempting to define patient characteristics that identify patients at risk for pressure sores.[13] The patient reported a history of pressure sores on his buttocks/thighs since becoming wheelchair bound after losing all sensation from mid-abdomen and down secondary to the complete spinal cord injury. Patient education was implemented for postural education through use of a lumbar roll and frequent skin checks after complaints and observation of skin irritation on the patient's lateral trunk.

There are several limitations to the study. As many outpatient PT settings, it is rare for the patient to see the same therapist upon each visit. Thus, treatment styles may vary, along with methods of carrying out interventions as well as decisions to continue or discontinue a particular intervention. It should also be noted that the therapist who performed the initial evaluation was not the same therapist that performed the re-evaluations throughout treatment as well as the discharge. The patient's initial evaluation was very limited, particularly in assessment of the ability to transfer in and out of the wheelchair. The patient's functional limitation was merely assessed by performing a "wheelchair push up" and a subjective report about the difficulty he was having in performing the transfer. It would be more beneficial to have a more descriptive, objective measure (amount of assistance required, time required, etc.) in order to track progress throughout therapy and compare baseline to end result to measure gains.

The facility where therapy sessions took place did not have equipment adaptable to patients in wheelchairs. Thus, the ability to use the variety of equipment available was very limited. There was often limited space, as it is a busy outpatient setting, to practice transferring. The patient mentioned toward the end of therapy that he is also having difficulty transferring on and off the toilet. He required the use of a transfer slide board in order to complete the task as well as close supervision from his wife. Unfortunately, we were not able to simulate the specifics of the toilet transfer due to limited space and equipment available in the facility. The therapists attempted to plan a toilet transfer simulation in the facility bathroom, however made a clinical decision not to perform the transfer due to the unhygienic nature as well as the safety concern that the toilet did not have a seat cover and as the toilet not being the correct height to practice on. The patient has several complaints about his wheelchair mechanics. The patient was in the process of having his wheelchair reevaluated. Unfortunately wheelchair evaluations were not

performed at this facility. The way a wheelchair fits can have an effect on the way a patient transfers as well. If time and resources permitted, a wheelchair evaluation would have been useful. Therapy may have been even more beneficial if his wife was present, especially in the initial stages when she was still providing assistance in transferring to and from the wheelchair. Patient and caregiver education is an integral aspect of therapy. The caregiver's role is valued as "the eyes and ears" outside of clinic. The role is to make sure the patient is performing the prescribed home exercise program, for example. Therapists often have to consider that caregivers themselves have a high risk for depression as well.[23] Having caregivers participate is a top priority because therapists can suggest methods to integrate input while decreasing strain on his or her body while providing care.[23] The intention behind having the patient's wife participate was so educate her on the level of independence required as well as body biomechanics to keep her safe while assisting her husband in transferring, if needed.

The following are a few suggestions for future research. The BTE visual BF system has multiple uses. The BTE was used only for isotonic shoulder/elbow extension and isometric scapular depression. Although this was useful for the goals of therapy as well as considering the limited allowed per session, the BTE system could have also been used for UE adduction (to assist in functional gains for toilet transfers), improved wrist strength, as well as digit strength. The BTE has been used extensively in research for wrist and digit strength strengthening and functional training. The facility where therapy took place was limited in providing tools and equipment to simulate functional tasks for the patient. For instance, the patient reported difficulty in toilet transfer. However, the facility did not have any safe means of simulating such a transfer with, for example, a handle or bar mounted on a wall. The patient was not able to use the traditional arm ergometer or other upper extremity strengthening and flexibility equipment

available to patients without paraplegia. Follow up with the patient was not conducted in order to assess the retention of gains made in therapy. In the future it may be beneficial to conduct a follow up visit or a phone call to the patient to assess carryover of gains made in therapy.

Conclusion:

Visual feedback combined with traditional PT to improve strength, ROM and balance was used to assist the patient to make functional gains, particularly in wheelchair transfers. The patient was progressed and benefitted from PT in order to have increased function when compared to his immediate post-op condition. The areas of improvement were overall decreased pain, self-reported functional use of the involved UE in transfers to and from the wheelchair, especially in leading with the involved left UE.

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Tables and Figures

Table 1. Values for Active ROM at Initial Evaluation

RIGHT		LEFT
160°	Shoulder flexion	155º
140°	Elbow flexion	140º
-5°	Extension	-10º
90°	Wrist extension	70º

Table 2. Values for MMT at Initial Evaluation

RIGHT		LEFT
5	Triceps	3
5	Bicep	4
5	Hammer curl	4
5	Shoulder extension	4-
5	Abduction	4
5	Flexion	4
5	Wrist flexion	4
5	Extension	4
120#	Grip	80#

Table 3. Isotonic Shoulder Extension Treatment Progress Comparing Initial and Final Treatment in Terms of Force, Work, and Power

Treatment Session	Force (Concentric/Eccentric(lbs)	Work (Joules)	Power (Watts)
Initial baseline treatment	28.0/ 28.0	1001.4	28.6
Final treatment	32.0/ 32.0	4800.8	96.0
% Difference	+14.3%/ +14.3%	+379.4%	+235.6%

Table 4. Strength Testing Values Obtained Comparing Initial Evaluation and Discharge

Initial Evaluation		Discharge
3/5	Elbow Extension	4-/5
4/5	Elbow flexion	5/5
4-/5	Shoulder extension	4-/5
4/5	Shoulder Abduction	5/5
4/5	Shoulder Flexion	5/5
4/5	Wrist flexion	4+/5
4/5	Wrist Extension	4+/5
80#	Grip Strength	90#

Figure 1. BTE isotonic left shoulder extension

Figure 2. BTE isometric left shoulder/elbow extension

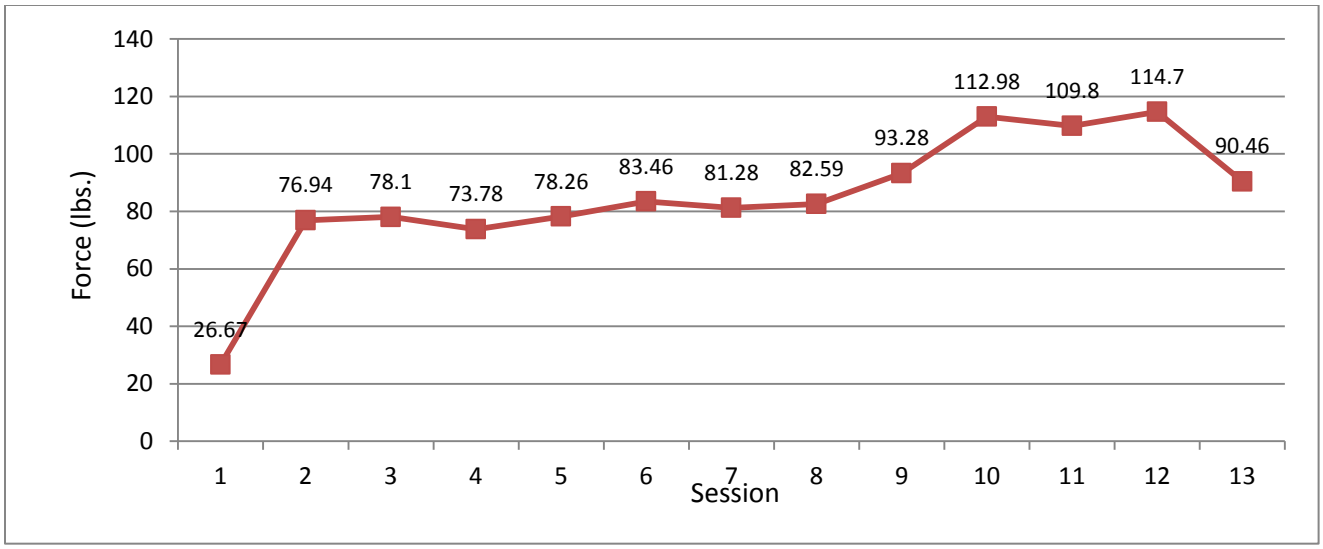

Figure 3. Isometric shoulder extension, average force per session

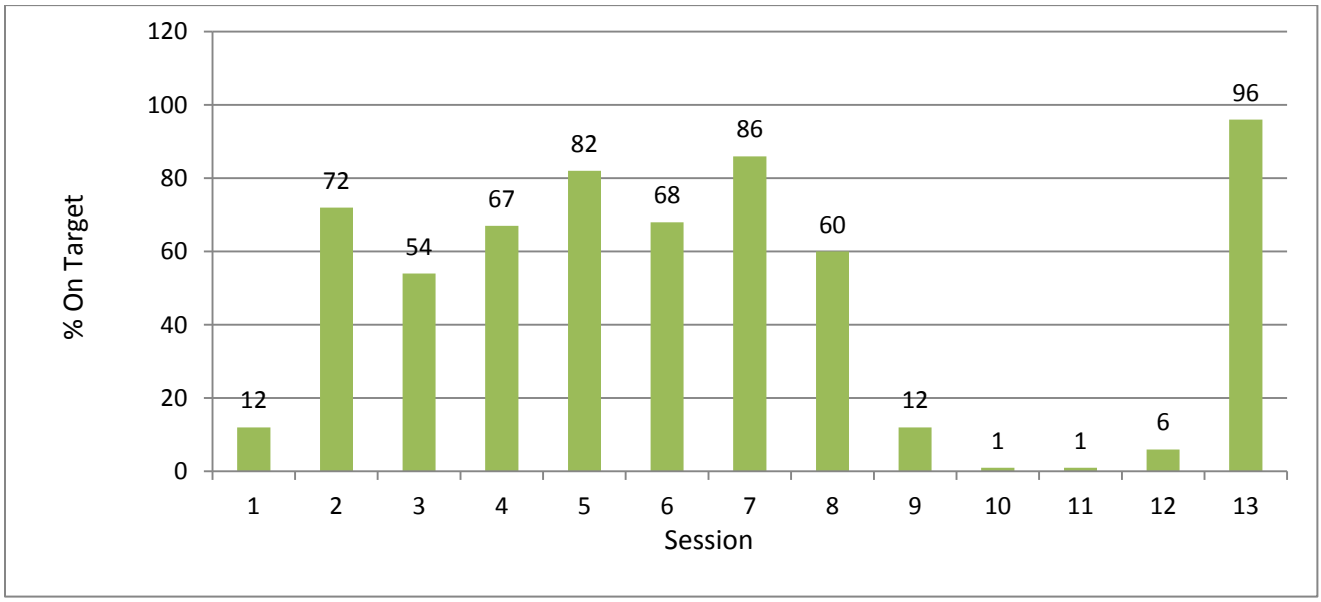

Figure 4. Isometric shoulder extension, % On target per session

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