

Use of Movement System Diagnoses in the Management of Patients With Neuromuscular Conditions: A Multiple-Patient Case Report

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PTJ's Focus on Diagnosis Special Series will be ongoing and is inspired by the "Defining the 'x' in DxPT" conferences. For background, read the editorial by Barbara J Norton on page 635.

Background and Purpose

Medical diagnoses are not sufficient to guide physical therapy intervention. To provide a rational basis for treatment selection by physical therapists, we developed a set of diagnoses at the level of impairment that are relevant to the human movement system. The diagnoses describe the primary human movement system problem and provide a basis for matching a specific problem with appropriate treatment. The purposes of this 3-patient case report are to illustrate an updated version of the diagnostic system and to show how treatment decisions can be made relative to both the movement system diagnosis and the patient's prognosis.

Case Descriptions and Outcomes

We diagnosed 3 patients with hemiplegia due to stroke as having 3 different movement system problems: force production deficit, fractionated movement deficit, and perceptual deficit. Specific intervention and actual patient outcomes for each case are outlined.

Discussion

Use of movement system diagnoses may have multiple benefits for patient care. The possible benefits include decreasing the variability in management of patients with neuromuscular conditions, minimizing the trial-and-error approach to treatment selection, improving communication among health care professionals, and advancing research by enabling creation of homogenous patient groupings.



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Every day, clinicians are faced with the task of selecting the most effective interventions for each patient. In medicine, ideally the task of selecting the most effective interventions is preceded by the task of diagnosing the patient's condition. Specifically, the physician first investigates the cause or nature of a condition, then decides on the appropriate diagnostic label, and finally selects the most suitable intervention. In physical therapy, we have acknowledged that making a diagnosis is part of our patient management model.¹ We also have acknowledged that medical diagnoses are not sufficient to direct physical therapy intervention.²⁻⁴ However, few clinically useful systems of diagnoses have been proposed, and none have been implemented on a wide-scale basis. The consequences of not having a diagnostic system are substantial. First, there is great variability in physical therapist practice, which we believe reduces the likelihood that all patients will receive the most suitable interventions. Second, there is little basis for creating the truly homogenous groupings of patients required to conduct meaningful, effective clinical research.

Previously, we described a set of human movement system diagnoses for patients with neuromuscular conditions.⁵ Our system is based largely on having performed systematic clinical observations for many years. The systematic observations enabled us to identify clusters of impairments that seemed to be key to the patients' problems. Recently, we revised the system to clarify ideas and simplify terminology. The system now consists of 9 diagnoses, each of which is a collection of impairment level signs that characterize and are labels for the patient's primary movement system problem (Supplemental Appendix 1, available online only at www.ptjournal.org).

In our system, the diagnosis is based on the results of diagnostic tests that are administered during a standardized clinical examination. The standardized examination includes tests for specific impairments and observational analysis of the manner in which critical tasks are performed. The tests for impairments are designed to identify deficits in motor control, muscle tone (level of hyperexcitability), muscle strength (force-generating capacity), nonequilibrium coordination, sensation, postural control, motion sensitivity, mental status, and joint range of motion. The critical tasks that are tested include: quiet sitting, quiet standing with feet hip's width apart and with feet together, step-up (placing one foot on a step and returning it to the floor), walking, walking while turning the head, stepping over obstacles, and walking forward and backward. All of the tests were selected because they measure movement variables that, in our clinical experience, enable us to differentiate among movement system problems.

When using our system, the physical therapist makes a diagnosis by first performing the standardized examination and then comparing the results for the patient to the criteria for the 9 categories. The online Supplemental Appendix 1 contains a definition of each diagnosis. In Supplemental Appendix 1, we have listed only the results of key tests and signs associated with each diagnosis, instead of specifying the results of every test in the examination. In some cases, the key tests are tests of impairments, and, in other cases, the key tests are results of task analysis. Although the diagnoses are not mutually exclusive, in most cases a patient will have only one diagnosis.

There are some cases in which more than one diagnosis may be appropriate. One example is a case in which a patient may have a pre-existing

movement system problem and then acquire a new movement system problem. Another example is a case in which 2 equally dominant movement system faults are thought to be limiting the patient's function. In other cases, the examination findings may match the description and key tests of a single diagnosis, but an additional patient characteristic is present that may alter the expected outcome. In these cases, a descriptor may be appended to the diagnosis (eg, movement pattern coordination deficit with impaired memory) (online Supplemental Appendix 1). The diagnosis (movement pattern coordination deficit) states the nature of the movement problem, and the descriptor (impaired memory) implies that the patient's ability to learn new strategies may be limited, thereby altering the expected outcome. Once the movement system diagnosis is determined, the therapist then considers the prognosis for recovery of the movement system fault and selects interventions appropriate to the patient's diagnosis and prognosis.

The purposes of this case report are: (1) to illustrate application of the diagnostic system on 3 patients with hemiplegia due to stroke and (2) to describe recent modifications of the system. Our focus will be on lower-extremity (LE) functions and balance. In addition to the examination findings used to make a diagnosis and an outline of the patients' procedural interventions, we will include the results of standardized tests used to quantify the patient's status. All patients consented in writing to participate as subjects of a case report. All of the patient examinations and interventions were completed by one of the authors (PLS).

Patient 1: Force Production Deficit

Patient Examination

History and systems review. The patient was a 56-year-old man who began physical therapy intervention in the outpatient setting 8 days after a left cerebrovascular accident. He complained of stumbling, difficulty producing speech, weakness in the right LE, and moderate difficulty with activities of daily living involving the right hand. Exploration of his past medical history revealed the following: a hereditary hearing loss, newly diagnosed hypertension for which he was receiving medication, and type II diabetes mellitus. He was preparing to retire from his job as a forklift driver, and he was a grain farmer. He was married, and his wife worked full-time. Aside from his insulin, he did not know the names of the medications that he was taking, but he reported that he took them as prescribed. His goals were to return to farming, to engage in work around his house, and to be able to play with his grandchildren.

Tests and measurements. The results of the examination for this patient are shown in Table 1.⁶⁻⁹ Unless otherwise indicated, the results are for the patient's right side, and the left side was normal.

The movement tests—fractionated movement (FM) and motoneuron response assessment (MRA)—are tests that were developed in our clinic and are described in detail in the online Supplemental Appendix 2. Fractionated movement is a measure that reflects the patient's ability to move at one joint without moving at other joints. The test was designed to identify important information about the movement system quickly and easily. In previous work,¹⁰ we demonstrated high interrater reliability coefficients (intraclass correlation coefficients [ICCs]) among 4 exam-

iners (ICC=1.00 for upper-extremity [UE] FM, ICC=.98 for LE FM) and significant correlations with the Motricity Index¹¹ for the UEs ($r=.71$) and the LEs ($r=.87$).

The MRA is designed to reflect the level of hyperexcitability of a patient with central nervous system dysfunction, particularly after stroke. Previous work¹² has demonstrated acceptable interrater reliability coefficients among 4 examiners (ICC=.93 for UE MRA, ICC=.74 for LE MRA) and some evidence of a correlation with the Ashworth Scale¹³ for the UEs ($r=.57$) and the LEs ($r=.58$). In contrast to the Ashworth Scale,¹³ the MRA provides information about reflex behavior both during and after cessation of voluntary effort rather than just during passive testing conditions.

Evaluation and Diagnosis

Summary of tests of impairments. The patient had a mild increase in muscle tone in the right UE and LE, but his movement in both limbs was fractionated when moving against gravity. His muscle strength was less than normal on the right side.

Summary of analysis of critical tasks. The patient demonstrated signs of fatigue and difficulty initiating a sit-to-stand movement. The initiation phase of a sit-to-stand movement is the phase in which the LE force demands are the greatest.¹⁴⁻¹⁷ The patient demonstrated hyperextension of the involved knee and a drop of the pelvis on the opposite side when he tried to bear weight on the involved side, such as during the step-up test (placing one foot up on a step and returning it to the floor), during gait, and when stepping over obstacles. Because there was no muscle shortness, the knee hyperextension and hip drop appeared to be due to an inability to support the joints during conditions of loading. The knee hyperextension and hip

drop persisted during repeated trials despite provision of both verbal instruction and manual support.

Considering all of the examination results together, the primary movement fault affecting this patient's mobility and balance was inadequate muscle force production. Therefore, the movement system diagnosis was force production deficit.

Prognosis for Motor Recovery

When estimating the prognosis for motor recovery, the physical therapist should consider not only the medical diagnosis but also the available literature on motor recovery, natural history of the condition, and effect of medical treatments on motor recovery. The therapist should consider whether there is good or poor potential for recovery of the movement-related impairments before selecting specific interventions. Patients with good potential for recovery are likely to benefit from interventions designed to remediate the impairment. Patients with poor potential for recovery are expected to benefit most from being taught compensatory movement strategies or accommodations.

Patient 1 had weakness due to a stroke. He demonstrated rapid motor recovery, as evidenced by his ability to move against gravity and fractionate movement within the first few days after his stroke. Based on a review of the literature related to motor recovery after stroke,¹⁸⁻²³ the patient's prognosis for further motor recovery was good.

Prognosis for Functional Recovery

After stroke, early and significant motor recovery, as seen in this patient, is related to maximal functional recovery.²⁴⁻²⁸ However, ongoing movement deficits persist even after mild stroke.^{29,30} Considering the data about motor and functional recovery

Movement System Diagnoses for Patients With Neuromuscular Conditions

Table 1.
Results of Force Production Deficit Initial and Posttreatment Examinations^a

Initial Tests of Impairments			Posttreatment Tests of Impairments	
Fractionated movement	UE: present at shoulder, elbow, wrist, hand, and first finger LE: present at hip, knee, and ankle		Fractionated movement	No change
Strength	Shoulder flexion 3/5	Hip flexion 4-/5	Strength	Hip flexion 4/5
	Shoulder abduction 3-/5	Hip extension 3/5		Hip extension 4-/5
	Elbow flexion 4-/5	Hip abduction 4-/5		Hip abduction 4/5
	Elbow extension 3+/5	Knee extension 4+/5		Plantar flexion 2/5
	Wrist extension 3/5	Dorsiflexion 4+/5		
	Wrist flexion 3/5	Plantar flexion 2/5		
	Hand flexion 3/5			
	Hand extension 3/5			
MRA	UE: moderate; LE: mild		MRA	No change
Sensation	No deficits in sensation of pain, temperature, or joint position sense		Sensation	No change
Initial Analysis of Critical Tasks			Posttreatment Analysis of Critical Tasks	
Quiet sitting	Essential movement components present		Quiet sitting	No change
Sit-to-stand	Able to stand from 45.7-cm (18-in) surface; left knee flexed more than right knee, with left foot placed farther back; apparent decreased weight bearing on right side; fatigued with 10 repetitions, as evidenced by increased use of momentum to initiate task and lack of full hip extension at termination of task		Sit-to-stand	Able to stand from 25.4-cm (10-in) surface; weight bearing appeared to be equal between left and right LEs
Quiet standing (feet hip width apart)	Able to stand unsupported without difficulty; no change with eyes closed compared with eyes open		Quiet standing (feet hip width apart)	No change
Quiet standing (feet together)	Able to assume position in first attempt with increased sway at hips; able to maintain position; center of mass shifted toward left side; no change with eyes closed compared with eyes open		Quiet standing (feet together)	Able to assume position on first attempt with no sway; weight bearing appeared to be equal between left and right LEs
Step-up (placed one foot on top of 20.3-cm [8-in] step and returned it to floor)	Able to complete task, alternating legs, 8 times; left lateral trunk flexion during right swing; left pelvic drop during right stance; right knee hyperextension during right stance; decreased left lateral trunk flexion with practice, but no other changes		Step-up (placed one foot on top of 20.3-cm step and returned it to floor)	Able to complete task, alternating legs, 8 times; sustained involved hip extension during involved-limb swing; involved knee without hyperextension

(Continued)

Table 1.
Continued

Initial Analysis of Critical Tasks		Posttreatment Analysis of Critical Tasks	
Gait	Ambulated without assistive device or physical assistance on smooth, level surface; line of progression deviated to right side; decreased right dorsiflexion at heel contact; hyperextension of right knee during right stance; left pelvic drop during right stance; line of progression improved with cues to focus on a visual target and with practice; speed=0.7 m/s (2.2 ft/s)	Gait	In-shoe heel lifts; line of progression straight on all surfaces; decreased right dorsiflexion at heel contact after 304.8 m (1,000 ft); hyperextension of right knee during right stance if tired; speed=1.2 m/s (4.0 ft/s)
Complex gait	Able to walk with head turning side to side without deviation in line of progression or instability; stopped before changing from forward walking to backward walking; stepped backward very slowly and deliberately; able to step over obstacle 10.2 cm (4 in) in diameter; mild instability when stance sustained on right LE when stepping over obstacle	Complex gait	Able to change from forward to backward walking without hesitation; no difficulty stepping backward; able to step over obstacle 45.7 cm (18 in) in diameter without instability or hesitation
Initial Standardized Measures		Posttreatment Standardized Measures	
Berg Balance Scale ⁶⁻⁸	52/56	Berg Balance Scale ⁶⁻⁸	54/56
Functional Independence Measure ⁹	Mobility subscale score: 20/21 Locomotion subscale score: 12/14	Functional Independence Measure ⁹	Mobility subscale score: 21/21 Locomotion subscale score: 14/14

^a Results pertain to the right side unless otherwise indicated. UE=upper extremity, LE=lower extremity, MRA=motorneuron response assessment.

after stroke and our own clinical experience, there was little doubt that this patient would walk independently without an assistive device in the home and in the community. Furthermore, we considered it likely that the patient would be able to walk for extended periods in the community with minimal gait deficits when brief rests could be incorporated into the activity. By contrast, we considered it likely that the patient would fatigue and demonstrate marked gait deficits when walking for extended periods (2 hours or more) without brief rests and with more vigorous activity such as climbing and running.

Intervention

Rationale. The rationale for selecting appropriate interventions for a patient with a movement system diagnosis of force production deficit is not based on direct evidence, because no intervention study has incorporated a group of patients with this specific movement system diagnosis. Based on logic, we determined that interventions for a patient with force production deficit and a good prognosis for recovery should be aimed at remediation of the primary movement fault of weakness through strength training.

There is a growing body of knowledge regarding the effectiveness of strength training in people who have had a stroke,³¹⁻³⁶ but it is difficult to determine how many study subjects were actually similar to patient 1. Based on the studies reviewed, it appears that strength training is safe³² in individuals who had a stroke at least 3 months prior to training and is related to improved performance in functional activities.^{31,33-36} However, evidence specific to people with *acute* stroke is limited. There is support from the National Clinical Guidelines for Stroke³⁷ developed by the Royal College of Physicians in London for using strength train-

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ing in individuals who have had a stroke; however, the guidelines do not state for which patients with stroke or in what phase of recovery a therapist should administer resisted exercise.

In addition, the American Heart Association/American Stroke Association-endorsed practice guidelines recommend “that strengthening should be included in the acute rehabilitation of patients with muscle weakness after stroke.”^{38(p e126)} More specifically, Carr and Shepherd³⁹ suggested that, in order to link improvement in muscle strength to improvement in functional performance, strength training should be oriented toward characteristics of tasks to be learned. After our analysis of the literature and based on our clinical experience, we believe that people with the diagnosis of force production deficit with a good potential for recovery after a central nervous system lesion may benefit from task-oriented training that is delivered in a resistance training paradigm (eg, performing 2–3 sets of 8–12 repetitions of the task at 60%–80% of the maximal resistance level, at a frequency of 2–3 times per week^{40–43}).

Specific interventions and response to treatment. The specific interventions for this patient are described in the online Supplemental Appendix 3, with additional comments below. Consistent with a strengthening paradigm,^{40–43} the intervention described was completed over 7 weeks at a frequency of 3 times per week. Sessions were generally 30 to 45 minutes long.

The patient was given in-shoe heel lifts to protect the posterior capsule of the knee from potential irritation and to improve the use of the quadriceps femoris muscle in controlling the knee during walking. The heel lifts placed the patient in relative plantar flexion at the instant of heel contact and during the stance phase



Figure 1. Patient with force production deficit practicing standing from a 30.5-cm (12-in) surface with the uninvolved foot slightly forward. The patient initially practiced from a higher surface and progressed to the 30.5-cm surface. The patient was encouraged to maximize the use of the involved (right) side during the task without compensatory movements.

of walking. Taping of the posterior aspect of the knee in an “X” with Leukosport tape* also provided a biomechanical block to knee hyperextension. When both the heel lift and tape were used, the patient did not hyperextend his knee during walking.

The therapist identified sitting down and rising to a standing position, stepping up and down on a step, and stair climbing as tasks that had high demands for force production and could be used for functional resistance training (Figs. 1, 2, and 3). In each of these tasks, the patient was cued to use the involved LE as much as possible. The tasks were made more difficult by modifying the height or incline of the surface and restricting use of the patient’s uninvolved limb.

The patient progressed slowly with exercise performed on resistance

* BSN-Jobst Inc, 100 Beiersdorf Dr, PO Box 390, Rutherford College, NC 28671.



Figure 2. Patient with force production deficit practicing stepping up on a 30.5-cm (12-in) stepping leading with the involved lower extremity. The patient practiced the task in 3 sets of 10 repetitions. He was encouraged to step up without compensatory trunk movements.

training equipment, and he reported significant fatigue after these exercises. The patient reported minimal to no muscle soreness in the 24 to 48 hours after each session.

Outcome

Results of the clinical examination at the end of the patient’s course of physical therapy intervention are provided in Table 1. Only those factors that changed are included in the table. The patient improved in the following: (1) ability to stand from low surfaces, (2) gait speed, (3) sustaining hip and knee extension during weight-bearing tasks, and (4) maneuvering over or around obstacles while walking without hesitating. He was able to chase his grandson across a room and run for short distances in the yard.



Figure 3. Patient with force production deficit practicing stepping down from a 30.5-cm (12-in) step leading with the uninvolvement lower extremity. The patient practiced from a 10.2-cm (4-in) surface initially and progressed to a 30.5-cm surface. The patient was encouraged to step down in a smooth, fluid motion.

Patient 2: Fractionated Movement Deficit

Patient Examination

History and systems review. The patient was a 55-year-old man who started physical therapy intervention in the outpatient setting 3 months after a right cerebrovascular accident. The patient reported that he was in an acute care hospital immediately after his stroke for less than 1 week and in the rehabilitation hospital for 1½ weeks. After his hospital discharge, he received physical therapy intervention at home until he began receiving care at the outpatient clinic.

The patient lived with his wife and had several children who lived at home intermittently. His wife assisted him with all activities of daily

living. He had a wheelchair at home but did not use it. Instead, he reported walking in his home with a hemi-walker (side-stepper). He had not fallen since he had returned home from the hospital. In addition to reporting significant difficulty in performing activities with his left hand, he complained of left shoulder pain. Prior to his stroke, he was employed at a tree nursery. At the time of his first outpatient visit, he was pursuing status as a disabled worker. Previous medical conditions included a small myocardial infarction 2 years prior to the stroke leading to the current episode of care and a previous stroke with no residual deficits 7 years prior. He had hypertension for which he was taking medication. He did not know the names of the medications he was taking, but he reported that he was taking them as prescribed. His goals were to walk in the community alone and to drive his truck.

Tests and measurements. The results of the initial examination are provided in Table 2. Unless otherwise indicated, all deficits were on the left side.

Evaluation and Diagnosis

Summary of tests of impairments. The patient was unable to fractionate movement of the left UE and LE, and the movement time of his left LE was increased as compared with both his right LE and with movement times of people without impairments.

Summary of analysis of critical tasks. The patient's nonfractionated movement was evident in his performance of each task. He was unable to modify the movement pattern in response to either cueing or instruction. He lacked the postural stability necessary to accommodate for his slow movements, and his instability was particularly apparent when he attempted to stabilize on the right LE while advancing the left

LE during a task. He became more unstable when he attempted to perform a lower-limb task at faster speeds.

Considering the tests of impairments and performance on critical tasks, the patient's diagnosis was fractionated movement deficit. Although some patients with stroke may demonstrate fractionated movement deficit in only the upper limb or the lower limb, patient 2 demonstrated this movement fault in both limbs.

Prognosis for Motor Recovery

The patient was not able to fractionate movement at one segment without movement at other segments. He also demonstrated a high level of motoneuron hyperexcitability, as evidenced by his MRA category. These findings along with the duration of his stroke (3 months) indicated that the quality of his movement was not likely to change, and the prognosis for motor recovery was poor.^{18-23,44-47}

Prognosis for Functional Recovery

An understanding of the patient's clinical signs within the first 2 weeks after the stroke would assist in determining the patient's prognosis for functional recovery.²⁵⁻²⁸ The patient reported that he was able to sit on the side of the bed without support in the first few days after his stroke. He also reported that he had always been continent in bowel and bladder. Retention of these abilities is associated with good functional recovery; their loss is associated with poor functional recovery.²⁵⁻²⁷ The patient's severe motor deficit and prior stroke are associated with poor functional recovery.^{26,27}

Given the patient's clinical picture, the literature on functional recovery after stroke, and our clinical experience with patients with FM deficit, we considered it likely that this patient would walk slowly but inde-

Movement System Diagnoses for Patients With Neuromuscular Conditions

Table 2.

Results of Fractionated Movement Deficit Initial and Posttreatment Examinations^a

Initial Tests of Impairments		Posttreatment Tests of Impairments	
Fractionated movement	Movement against gravity but nonfractionated in shoulder flexion, hip flexion, and knee extension; no other movement	Fractionated movement	No change
Strength	Unable to fractionate movement even in gravity-neutralized positions	Strength	No change
MRA	UE: marked; LE: severe	MRA	No change
Sensation	Impaired joint position sense at ankle	Sensation	No change
Initial Analysis of Critical Tasks		Posttreatment Analysis of Critical Tasks	
Quiet sitting	Able to sit unsupported; center of mass shifted to right side	Quiet sitting	No change
Sit-to-stand	Unable to stand from 50.8-cm (20-in) surface without UE support; able to stand from 50.8-cm surface with right UE support; decreased weight bearing on involved side; slow to initiate; lack of full hip and knee extension on termination; loss of balance posteriorly at termination; able to recover balance by stepping; some improvement with anterior weight shift during execution with practice and manual guidance to assist dorsiflexion of tibia over foot	Sit-to-stand	Able to stand from 38.1-cm (15-in) surface with UE support; decreased weight bearing on involved side; slow
Quiet standing (feet hip width apart)	Able to stand unsupported for 30 s; involved hip and knee flexed; increased sway at ankle (uninvolved limb) with eyes closed	Quiet standing (feet hip width apart)	No change
Quiet standing (feet together)	Required assistance to assume feet-together position; able to stand 15 s; swayed at hips; some improvement in amount of sway with repetition; increased sway with eyes closed	Quiet standing (feet together)	No change
Step-up (placed one foot on top of 20.3-cm [8-in] step and returned it to floor)	Needed assistance to attempt task; very slow to flex involved hip and knee and unable to do so through sufficient range of motion; unable to balance on uninvolved LE during attempts to swing involved LE; unable to modify strategy	Step-up (placed one foot on top of 20.3-cm step and returned it to floor)	Needed assistance to attempt task; very slow to flex involved hip and knee and unable to do so through sufficient range of motion; unable to modify strategy
Gait	Ambulated with moderate hand-hold assistance; gait characterized by the involved foot crossing midline, decreased weight bearing on the involved side, hyperextension of the involved knee during stance, inadequate hip flexion during swing of the involved side with substitutions of hip lateral rotation and adduction, and decreased step length on the uninvolved side; independent with hemi-walker (side-stepper) and prefabricated AFO; standby assistance with large-base quad cane due to instability during swing on the involved side; unable to modify movement strategy for left swing; speed=0.1 m/s (0.2 ft/s)	Gait	Speed=0.2 m/s (1.71 ft/s) with straight cane and left AFO; characterized by decreased weight bearing on the involved side, inadequate hip flexion during swing of the involved side with substitutions of hip lateral rotation and adduction, and decreased step length on the uninvolved side
Complex gait	Moderate assistance due to instability for ambulation with head turning and stepping backward; maximal assistance to step over object	Complex gait	Able to walk outdoors, step up and down on a curb, and step over a low object with a cane; able to carry light objects indoors with right hand
Initial Standardized Measures		Posttreatment Standardized Measures	
Berg Balance Scale ⁶⁻⁸	25/56	Berg Balance Scale ⁶⁻⁸	43/56
Functional Independence Measure ⁹	Mobility subscale score: 10/21 Locomotion subscale score: 7/14	Functional Independence Measure ⁹	Mobility subscale score: 18/21 Locomotion subscale score: 12/14

^a Results pertain to the left side unless otherwise indicated. UE=upper extremity, LE=lower extremity, AFO=ankle-foot orthosis.

pendently in the home without an assistive device and in limited outdoor settings using an assistive device. We considered it unlikely that he would be independent with more ambitious activities such as repeated, rapid squatting and stooping or lifting and carrying moderately heavy objects using both limbs. Likewise, we considered it unlikely that he would be independent with bimanual activities of daily living or tasks involving the left hand only.

Intervention

Rationale. As with the diagnosis for the first patient, the rationale for selecting interventions is not based on direct evidence from the literature, because no intervention study has included a group of patients with this specific movement system diagnosis (ie, FM deficit). In this case, the literature related to prognosis for motor recovery guided our intervention strategy. Because of the patient's poor potential for motor recovery, correcting the patient's movement patterns was not a part of the treatment plan. Rather, the overall treatment objective was to improve the patient's postural stability when performing the compensatory movement strategies he needed to use because he was not able to fractionate movement. In order to provide sufficient opportunity for practice of sufficiently complex postural stability tasks, the therapist recommended daily sessions for 2 to 3 weeks; however, the patient was unable to arrange transportation for this treatment frequency. As a result, the patient was treated 2 to 3 times per week for 8 weeks; each session lasted 45 to 60 minutes. The procedural interventions for this patient are detailed in the online Supplemental Appendix 4 and are highlighted below.

Specific interventions and response to treatment. During the first week of treatment, the patient



Figure 4.

Patient with fractionated movement deficit walking with straight cane during first week of therapy. The patient was unstable sustaining weight on the uninvolved (right) lower extremity while he attempted to advance the involved (left) lower extremity.

practiced walking on level surfaces while using a straight cane. The patient's greatest challenges during walking were: (1) balancing on his right LE (uninvolved limb) during left LE (involved limb) swing, (2) regulating his right LE step length relative to his degree of stability on the left LE, and (3) consistently placing his left foot appropriately (Fig. 4). He used compensatory movement strategies, that is, lateral trunk flexion and hip hiking (elevation of the pelvis), to swing his left LE. Practice was aimed at improving the consistency of this movement strategy to ensure more consistent foot placement and stability. He was encouraged to practice walking at home with the straight cane when someone was nearby; but, because of fear of falling, he did not follow through with consistent practice at home until his third week of therapy.

The patient began stepping over obstacles in the first 2 weeks. He prac-

ticed stepping over obstacles, leading with both the left and right feet. His foot placement was more consistent when leading with the right foot, and this was the strategy that he was instructed to use.

During the third and fourth weeks of his therapy, the patient began to practice retrieving objects from the floor from a standing position. During his initial attempt at retrieving an object from a 30.48-cm-high (12-in-high) surface, he moved very slowly and started to fall backward when he began his return to an upright position. However, within a few trials, he was able to retrieve an object from the floor very slowly and to return to the standing position without loss of balance. Within 2 sessions, he was successful in retrieving objects from the floor on his initial attempt, but he still moved slowly.

The patient first attempted walking without an assistive device during the fifth week of therapy. He was able to walk only 3 to 4.6 m (10–15 ft) before he needed physical assistance with balance. With the increased postural demands of walking without a device, he again had difficulty with consistency of left foot placement. Within one session, he learned to decrease the length of steps he attempted to take, and he was able to walk up to 3 m (10 ft) without either using an assistive device or losing his balance.

The patient began practicing standing up from and sitting down on a 50.8-cm (20-in) sitting surface during the first week of therapy. He was most successful if he used his right foot to help him flex his left knee so that his foot was positioned underneath him for standing.

The patient initially attempted to climb stairs while using a railing during the first week of therapy. However, the task was too difficult for



Figure 5.

Patient with fractionated movement deficit using partial body-weight support system in order to improve endurance and speed with walking.

him for a number of reasons: he required complete support for balance, his left LE crossed midline with each attempt, and he was unable to correct these problems with practice. As a result, this task was considered to be too difficult to be therapeutic at that time. Stair climbing was evaluated each week but not practiced until the patient's stability with compensatory strategies was improved, and he was able to complete the task with only moderate assistance instead of maximal assistance.

The patient also practiced opening and closing doors while walking, carrying objects in his right hand while walking, and transferring to and from the floor. On his first attempts of these more complex tasks, he often had difficulty developing a successful movement strategy. However, once instructed in a possible strategy, he was generally successful by the second or third trial.

The therapist used the LiteGait partial body-weight support system[†] (Fig. 5) to improve walking endurance and speed. Initially, 30% to 40% of the patient's body weight was supported.⁴⁸⁻⁵⁰ At first, he was too fatigued to walk longer than 10 minutes. For a while, the patient practiced walking both with and without an ankle-foot orthosis (AFO), but because his left foot placement was more consistent with the AFO, subsequent practice was done with the AFO.

During the last 2 weeks of therapy, the patient continued to practice all of the outlined tasks with an increasing emphasis on consistency of performance, flexibility of performance under varying environmental constraints, and efficiency.⁵¹ This practice included walking outdoors and transferring in and out of the patient's truck.

Outcome

Results of the examination at the end of treatment are in Table 2. Only those factors that changed are included in the table. The patient showed improvement in his balance, independence with gait and stair climbing, ability to stand up from and sit down on a variety of surfaces (Fig. 6), ability to perform complex gait activities, and slight improvement in gait speed. He was slow but able to retrieve a pen or pencil from the floor, carry a bag of groceries short distances, open and close doors while walking with or without a cane, sit down and stand up from the floor without a chair or other support, step over a low object with a cane, step up and down a curb with a cane, walk outdoors with a cane, and ascend and descend a flight of stairs using a reciprocal pattern with the aid of a railing.

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Figure 6.

Patient with fractionated movement deficit standing up from 38.1-cm (15-in) surface after 6 weeks of therapy. The patient was independent with standing from a variety of surfaces, including chairs on wheels.

Patient 3: Perceptual Deficit Patient Examination

History and systems review. The patient was a 76-year-old man who was admitted to the hospital from the emergency department with complaints of left-sided weakness 1 day prior to the initial physical therapist examination. He was found to have a right middle cerebral artery infarct and atrial fibrillation. After 1 week, his condition deteriorated somewhat, and he was found to have a new hemorrhage in the right basal ganglia. His medical history included hypertension, hyperlipidemia, B₁₂ deficiency, and a urinary tract infection.

Prior to having a stroke, the patient was retired but was quite active around his home and in the community. He required no assistance with activities of daily living, he was able to drive a car, and he particularly enjoyed yard work. He lived with his wife, who was in good health. His

medications were adjusted during his stay in the hospital and, at discharge, included medications for all of the conditions in his history. The patient was unable to articulate specific goals but wanted to “get better.”

Tests and measurements. The initial physical therapist examination was completed on the first day following the stroke. When the therapist entered the room in the intensive care unit, the patient was found lying in the bed with his head turned completely to the right. He was receiving 2 L of oxygen, and his vital signs, heart rhythm, and oxygen saturation were being monitored electronically. The results of his initial examination are shown in Table 3. In addition to these results, the therapist noted that the patient was awake, lethargic, and oriented. He was able to follow commands to perform 1- and 2-step movements, made jokes, and was somewhat restless. During the examination, he had difficulty maintaining his level of alertness.

Evaluation and Diagnosis

Summary of tests of impairment and analysis of critical tasks. Although the patient had a number of substantial impairments, including weakness of the left side, a left visual field loss, and disregard for the left side, the primary movement problem that affected this patient’s mobility was his resistance to correction of vertical orientation. This statement is justified by the following line of reasoning. When the patient attempted to sit up straight, he fell to the left side. When the therapist attempted to correct the patient’s postural alignment, the patient resisted correction to the midline position. The patient’s weakness may have explained why he fell to the left side, but weakness did not explain why he shifted his weight toward that side and resisted correction to the midline position. In our experience, patients who are weak and have an

accurate internal reference for postural orientation shift their weight toward the uninvolved side.

Similarly, the patient’s left visual field loss may have explained why he shifted his weight toward the left side but would not explain why he resisted correction to the midline position. In our experience, patients with a visual field loss may shift their weight toward the side of the visual field loss, but they are able to orient to a midline position with minimal cues and guidance. The fact that the patient resisted correction to the midline position suggested that he had a faulty internal reference for postural orientation.³⁹ In our experience, all patients who resist correction to vertical orientation have disregard for the involved side, but not all patients with disregard for the involved side resist correction to vertical orientation.

Based on the results of the tests and the observations of our clinical examination, this patient’s movement system diagnosis was perceptual deficit. The patient had a distorted sense of the vertical, and he resisted correction of midline position. To be more specific, we could add a descriptor “with visual field loss” if so desired.

Prognosis for Functional Recovery

Disregard for the involved side and poor postural control after stroke are associated with a poorer prognosis for functional independence and with a slower rehabilitation course than is expected when there is no disregard and good postural control.⁵²⁻⁵⁶ Although this patient’s sitting balance was very impaired initially, he was able to modify the strategy he used when sitting up from a right side-lying position. His lethargy significantly affected the therapist’s ability to identify how readily he was able to modify his

motor performance with practice. Given his very acute status, his ability to follow instructions (even though lethargic), and his other findings, we considered it likely that within 4 weeks the patient would be able to sit unsupported. We also considered it likely that he would require minimal assistance with transfers and be unlikely to use ambulation as a means of locomotion.^{27,28,57,58}

Intervention

Rationale. In contrast to the situation for the first 2 cases, a rationale for intervention selection related to the perceptual deficit diagnosis can be based on direct evidence from the literature. In general, we agree with the principles previously described by Karnath and colleagues⁵⁹⁻⁶¹ for patients with contraversive pushing. Consequently, the procedural interventions were focused on increasing the patient’s awareness of his postural control deficits, teaching him movements necessary to find a balanced position, and increasing his ability to maintain a balanced position while completing other movements. In addition, the therapist developed a plan for increasing the patient’s tolerance to the upright position. The patient was treated in the acute care hospital for 2 weeks prior to being transferred to a rehabilitation hospital in another town. He tolerated 20 to 30 minutes of physical therapy intervention daily during the first 10 days after his stroke and 30 to 40 minutes per day during the last 4 days of his hospital stay. The procedural interventions for this patient are outlined in Supplemental Appendix 5 (available online only at www.ptjournal.org) and are described below.

Specific interventions and response to treatment. In all upright tasks, including sitting in a “cardiac” chair, the patient was encouraged to align himself with door jams, window frames, and other ver-

Movement System Diagnoses for Patients With Neuromuscular Conditions

Table 3.
Results of Perceptual Deficit Initial and Posttreatment Examinations^a

Initial Tests of Impairments		Posttreatment Tests of Impairments	
Fractionated movement	No movement in any muscle groups in UE or LE	Fractionated movement	No change
Strength	No movement in any muscle groups in UE or LE	Strength	No change
MRA	UE: mild; LE: moderate	MRA	No change
Other	Abnormal flexor withdrawal reflex in LE	Other	No change
Sensation/disregard	Absent touch and pain sensation in UE; left visual field loss; visual disregard for left side but able to track with eyes and move head just past midline to left side	Sensation/disregard	No change
Initial Analysis of Critical Tasks		Posttreatment Analysis of Critical Tasks	
Quiet sitting	Unable to sit unsupported; center of mass shifted to left (involved) side by fixing distal right UE and extending arm; no weight bearing on left side; resisted correction of center-of-mass alignment; "pushing" behavior	Quiet sitting	Able to sit once placed with feet supported, back unsupported up to 30 s; attempted to correct losses of balance by fixing distal right UE and extending arm, which resulted in "pushing" behavior; resisted correction of center-of-mass alignment
Sit-to-stand	Unable	Sit-to-stand	From 61-cm (24-in) surface; moderate assistance without UE support and controlling right foot placement; supported by a bedside table; demonstrated "pushing" behavior if distal right UE fixed and right LE allowed to move laterally
Quiet standing (feet hip width apart)	Unable	Quiet standing (feet hip width apart)	With support of bedside table; cued to shift weight to right side; support needed for left knee; unable to bear weight on left side; able to maintain supported but balanced position for 10-15 s at a time
Quiet standing (feet together)	Unable	Quiet standing (feet together)	No change
Step-up (placed one foot on top of 20.3-cm [8-in] step and returned it to floor)	Unable	Step-up (placed one foot on top of 20.3-cm step and returned it to floor)	No change
Gait	Unable	Gait	No change
Complex gait	Unable	Complex gait	No change
Initial Standardized Measures		Posttreatment Standardized Measures	
Berg Balance Scale ⁶⁻⁸	0/56	Berg Balance Scale ⁶⁻⁸	No change
Functional Independence Measure ⁹	Mobility subscale score: 3/21 Locomotion subscale score: 2/14	Functional Independence Measure ⁹	Mobility subscale score: no change Locomotion subscale score: no change

^a Results pertain to the left side unless otherwise indicated. UE=upper extremity, LE=lower extremity, MRA=motorneuron response assessment.



Figure 7. Patient with perceptual deficit in a resting position of sitting while supporting himself on the right (uninvolved) forearm. The patient's "pushing" behaviors were consistently decreased in this position.



Figure 8. Patient with perceptual deficit practicing actively moving from the right forearm support position to an upright sitting position. The activity was terminated if the patient began "pushing" his weight toward the involved (left) side.



Figure 9. Patient with perceptual deficit practicing standing at bedside with forearm support on uninvolved side. Assistance was provided to support the involved knee and to prevent a fall. The patient was asked to shift his right hip toward the table.

tical objects within his visual field. The patient's ability to concentrate and focus on these instructions was limited to seconds at a time.

Because the patient had significant difficulty shifting weight from the left side to the right side, he was moved into a sitting position from a right side-lying position. Using this method, weight was already on his right hip before he attempted to move to a sitting position. His "pushing" behavior was consistently controlled when leaning on the right forearm with the elbow flexed in a sitting position. This position was used as a resting position whenever the patient lost his balance and demonstrated "pushing" behavior (Fig. 7). He practiced assuming an upright sitting position by moving from the resting position to a sitting position by lifting the arm from the bed and straightening his trunk to sit (Fig. 8).

The patient practiced coming to a standing position from a sitting posi-

tion. He was prevented from using his right UE to assist with standing because doing so increased the pushing behavior. A bedside table was placed on the patient's right side, and he was cued to either reach his hand in the air or slide his hand toward the right front corner of the table while shifting his right hip toward the table (Fig. 9). He was able to achieve some active weight shift to the right side on his initial attempts with this activity.

The patient practiced maintaining his balance while moving his head from side to side and by moving either the right UE or LE while in the following positions: sitting and leaning on the right forearm, sitting in a chair without armrests, and standing. He consistently fell to the left side with each effort.

An initial part of the plan for the patient involved teaching the nursing staff to work with him on im-

proving vertical tolerance. The therapist identified an appropriate chair-and-transfer strategy so that the patient could be out of bed at regular intervals. The nursing staff performed a passive transfer from the bed to a "cardiac" chair; using the cardiac chair was advantageous because it flattened like a bed for the transfer and then easily converted back to a chair. The patient sat in the chair 30 to 45 minutes, 3 times per day.

Outcome

The results of the examination just prior to discharge from the acute care hospital to the rehabilitation hospital are shown in Table 3. Only the factors that changed are included in the table.

Discussion

We have demonstrated that 3 patients with the same medical diagnosis had 3 different movement system diagnoses, each of which required a different set of interventions. We be-

lieve that, by focusing on the movement system rather than the medical diagnosis, we can categorize patients in ways that are distinctly meaningful for physical therapists. More specifically, by using a distinct set of movement system diagnoses, coupled with an understanding of the prognosis for recovery, we can most appropriately guide selection of interventions and facilitate research designed to test the effect of interventions. The set of movement system diagnoses for neuromuscular conditions that we have developed is at least a beginning for how to organize our thinking about diagnosis.

Benefits of System

Using a diagnostic system for the movement system as a basis for physical therapist practice improves the care of patients in 4 important ways: (1) therapists can follow a pattern of care for patients with similar movement system problems leading to less variability among providers, (2) therapists can target treatment toward a specific movement problem from the beginning of an episode of care with less reliance on trial and error, (3) therapists can communicate clearly with one another and with third-party payers, and (4) researchers can focus their studies on testing the effectiveness of movement interventions on patients with different types of movement problems rather than different types of diseases. We will now discuss each of these features of clinical practice in more detail.

Organizing practice around a focus on the movement system and a set of movement system diagnoses decreases variability in practice in at least 3 ways. First, before making a diagnosis, physical therapists should perform a standardized clinical examination; doing so ensures that all patients are examined in the same way. Second, use of the standardized examination in concert with the def-

initions for the diagnoses ensures that all therapists arrive at the same diagnosis for a particular patient. Third, use of a system in which movement-related interventions are linked to specific movement system diagnoses ensures consistent treatment selection among therapists. Decreased variability in medical practice has been shown to improve the process and outcome of clinical care.^{62,63} We expect that decreased variability in physical therapist practice will yield similar benefits for patients.

In standard physical therapist practice, there is no framework for selecting from among the vast array of strategies available to the therapist. As a result, standard physical therapy care for patients with neuromuscular conditions is often a process of trial and error, with related inefficiencies. When applying our system, therapists are directed toward strategies that we believe will either remediate impairments or assist in developing alternative compensatory movements,^{26,64,65} depending on the patient's movement system diagnosis. With less trial and error in practice, the patient is able to maximize the available practice time by focusing only on those interventions that are most likely to be successful.

A system of diagnosis for physical therapy is useful in communicating with colleagues. A known, agreed-on set of labels for conditions that physical therapists manage will help colleagues develop an immediate mental picture of the patient as well as formulate ideas about intervention. A system of diagnoses also is useful in communicating with third-party payers, who—in our experience—have been responsive to requests for additional services for some patients because they see that we use fewer resources for other patients.

Finally, using a set of movement system diagnoses as the basis for grouping patients in clinical research studies may increase the likelihood that results will demonstrate the effectiveness of interventions and be more readily applicable in the clinical environment. Historically, subjects in intervention studies have been grouped based on their medical diagnosis; in some cases, subjects have been further categorized based on the severity of their condition. For example, some authors⁶⁶⁻⁶⁸ have suggested that constraint-induced movement therapy (CIMT) is effective for improving UE function in patients who have had a stroke. Other authors⁶⁹ have suggested that CIMT may be effective for other conditions such as focal hand dystonia. In both conditions, the movement deficits of the patients are relatively mild. The unanswered question is whether CIMT is an intervention that appears to be effective for people who have specific medical diagnoses or an intervention that is effective for people with relatively mild movement system problems. In order for results to be more readily applicable to the clinical setting, the movement system interventions that we use might best be studied for their effectiveness on a given state of the movement system as opposed to a given disease. We believe that a set of movement system diagnoses such as ours may be at least a starting place for categorizing patients and that, if it is used by researchers, the results will be very beneficial for patients.

Limitations

Our movement system diagnoses for patients with neuromuscular conditions are focused on the diagnosis and prognosis aspects of patient management. They do not attempt to account for the context of the patient's care as defined by the patient's roles, support system, goals, or other variables. When using our system, the diagnosis is the move-

ment system problem, and the prognosis is the potential for improvement. The context of the patient's case focuses the therapist on activities that are important and meaningful to the patient while holding fast to treatment principles that are consistent with the diagnosis and prognosis.

Our movement system diagnoses for patients with neuromuscular conditions have not been validated by research. Although our ideas have some face validity through repeated clinical use and implementation in various clinical settings, we have not tested our ideas through controlled studies. These studies are needed.

We do not have any evidence regarding the relationship between our movement system diagnoses and performance on standardized measures. For example, we can postulate that patients with movement pattern coordination deficit, force production deficit with a good prognosis for recovery, and sensory selection and weighting deficit will perform better on the Berg Balance Scale⁶⁻⁸ than patients with sensory detection deficit or hypermetria (Supplemental Appendix 1, available online only at www.ptjournal.org). However, we do not know whether patients with sensory detection deficit and hypermetria will perform differently from each other on the Berg Balance Scale.⁶⁻⁸ We do not believe that performance on standardized measures will prove to be diagnostic for movement system problems, but the relationship could be studied.

Conclusion

We have described a set of impairment-level movement system diagnoses for patients with neuromuscular conditions and have demonstrated use of the diagnoses with 3 patients. The set of diagnoses may have multiple benefits for clinical practice and research because it pro-

vides a framework for identification and management of specific human movement system problems.

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