A Question of Flexion

PREVENTING KNEE HYPEREXTENSION IN THE ADULT

By Monica Diamond, MS, PT

How can I control the knee?" This is one of the most common questions asked by therapists treating individuals recovering from stroke. Patients are frustrated as well—they are afraid to let the knee flex, as it may "collapse," but they can't find and control that happy medium between flexion and "locked" extension.

The solution to the problem is not straightforward. Control of the knee is complex and depends not only on a balance of muscle activity at the knee, but on many other factors including:

- the biomechanical relationships between body segments as the body moves through space
- sensory awareness at the knee as well as other parts of the body
- correct timing and sequencing of muscle activation in the lower extremity as well as the rest of the body
- complex control of rotational forces resulting from muscle activity
- transmission of forces during weight acceptance and transfer

As always, examination and evaluation of the factors contributing to the movement problem are essential before any intervention can be considered. We'll first look at the steps of evaluation and examination and then address treatment strategies.

EXAMINATION

According to the NDT Enablement model (Howle 2002). the patient's functional gait and the posture and movement components are assessed initially. Based on the information gathered, the underlying system impairments are hypothesized and tested.

Through a combination of observation and interview, the extent and relevance

Examination of Functional Gait

Depending on the setting,

functional gait is evaluated through a combination of observation and interview. For the specific problem of knee hyperextension, it is critical to note the relevance of this movement problem to the patient's function, both now and anticipated. Knee hyperextension observed during gait may contribute to difficulty in other functions, such as difficulty initiating knee flexion to climb stairs or sit down. Often review of function combined with observation of the posture and movement aspects of the patient's gait suggests underlying possible causal factors, or system impairments. Functional abilities and limitations, both present and anticipated, are the key to determining the relevance of the multitude of "symptoms and problems" often observed in the gait of the individual with neuropathology.

of the patient's problem with knee control is determined, since the individual frequently demonstrates better control in the clinic during the exam than he or she does when involved in the performance of functional tasks.

Examination of Posture and Movement Components

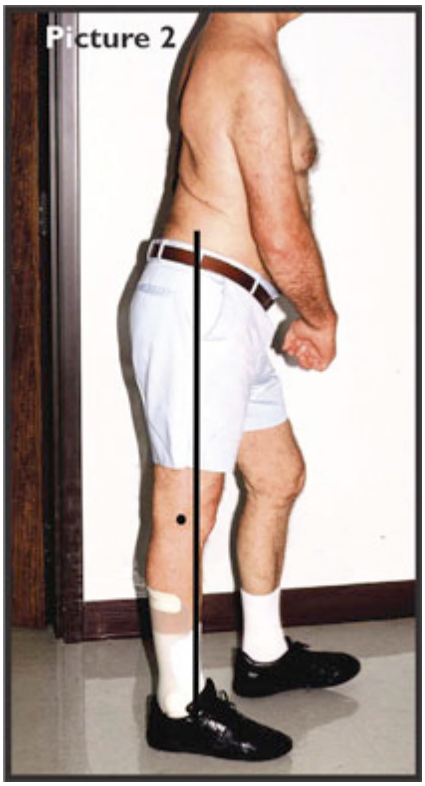
Observation and therapeutic handling are used to assess the individual's gait pattern. The posture and movement components demonstrated by the patient are assessed thoroughly, including such things as symmetry, weight shift, alignment, relation of the center of mass to the base of support, and gait characteristics such as stance and swing time, cadence, etc.

Look for the following indications of effective control:

- **Body alignment.** Is the body aligned correctly while the patient is standing and walking? The upper body should be aligned over the pelvis, and the

propulsion of the body in normal gait comes from the feet. Patients who are trying to move forward with inadequate control in the lower extremities (LE) often lead or pull forward and toward their strong side with the upper body. The resulting biomechanical situation leaves the pelvis behind the knee and can force the knee into hyperextension. (See Pictures 1 and 2). Use of an assistive device often contributes to this problem since it encourages the forward lean of the upper body. Excessive trunk flexion may cause a similar problem, but patients may also find a way to "lock" the knee mechanically using a more complex shift – shoulders back, pelvis forward, knee back, etc. (See Picture 3).

- **Direction of motion.** Is the primary direction of motion of the body forward, with slight but symmetrical lateral weight shifts for stability during stance? Further assessment may call attention to the source of a movement progression deviation, such as a



Pictures 1 and 2 show a schematic representation of the line of gravity falling anterior to the knee joint axis, resulting in a force toward knee hyperextension. **Picture 3:** This patient

"too wide" base of support contributing to excessive lateral weight shift.

- **Movement of the hip of affected leg.** Is the affected hip continuing to move forward over the foot throughout stance? Hip extension should be occurring throughout stance. Patients often substitute lumbar extension for hip extension or may continue progression forward via the upper body.

has created a situation in which his knee can be stable but, unlike the patient in picture 1, he has not used a posterior pelvis position to create the stability. Since he has relatively mobile joints, he is able to "hang" anteriorly at the hip and to use a combination of relatively inactive joint positions to provide enough stance stability so he can progress his strong leg forward in swing.

- **Ankle.** Is the ankle adequately stable and mobile to allow heel strike as well as progression of the tibia forward over the foot in stance? Landing with the forefoot first creates a backward force through the tibia which can contribute to forceful knee extension. This can result from unbalanced or excessive plantarflexion, inadequate activation of dorsiflexors, or range limitations.
- **Lower-extremity movement.** Is movement of the affected LE smooth and primarily in the sagittal plane, or are there apparent rotational deviations through the affected LE or the rest of the body? These may be more obvious in distal components such as the supinated foot during swing, but are usually complex and compensatory, with rotations and counter rotations occurring throughout the kinetic chain.
- **Knee extension movement.** Does the movement into knee extension occur smoothly and without excessive external rotation of the tibia? Normal knee extension is accompanied by external rotation of the tibia, called the "screw home" or" locking mechanism"(Neumann 2002). In patients with excessive knee extension, unbalanced muscle forces often result in forceful and excessive external rotation of the tibia (often with ankle inversion). The ability of the patient to "unlock" the knee in a smooth and graded manner for function will depend on the ability to internally rotate the tibia with stable and controlled segments above and below the knee.
- **Weight transfer over affected leg**. Does the patient smoothly transfer weight forward through the heel, then the ball of the foot as the body moves forward? Lack of mobility and

inadequate activation of plantar flexors may limit propulsion and the effectiveness of ground reaction force for weight shift.

As described in the examples above, during observation you are also beginning to hypothesize as to the underlying system impairments that might be responsible for each of the faulty movement components observed.

Adding Handling to Examination
Therapeutic handling can be used to gather more information, and to assist with prioritizing which of the patient's posture and movement problems are most significant.
For example:

- Using handling, attempt to correct asymmetries and faulty alignment. What do you feel? Hands-on assessment often clarifies cause/effect relationships. For example, consider the individual whose upper body is leaning forward with pelvis behind the foot throughout stance. By facilitating correct posture (body upright, shoulders over pelvis, and upright trunk progressing over the foot in stance), it's often possible to feel which is more significant: whether it is the "lean" or pull of the upper body, or the lack of stabilization posteriorly at the hip.
- Are movements of the lower extremity free in all directions or does the patient move only in limited patterns? Attempting to facilitate correct components can clarify the active/passive nature of faulty components. For example, if you are (carefully!) facilitating knee flexion in late stance in preparation for swing, you may feel a passively extended knee that can be flexed relatively easily with facilitation. In contrast, you may feel a strong active resistance to knee flexion, suggesting overactivity of knee extensors and incorrect timing of quads and hamstrings.
- With handling, you gain information about the patient's sensation and perception of touch and movement. These initial impressions will contribute to your initial assessment and may be investigated in more detail as needed.

Determining Underlying Impairments in Specific Systems
If you've gotten this far, you may be getting "antsy" for the solution to the problem. This is significant, because as therapists, we frequently address knee hyperextension and other frustrating treatment problems by jumping into various intervention "ideas" before we have adequately diagnosed the cause of the movement problem. Time spent on a focused and thorough examination and evaluation process can lead to more effective and targeted intervention with improved treatment outcomes.

Examination and evaluation continue somewhat simultaneously as the NDT therapist makes observations and begins to hypothesize their cause and relevance. Based on hypothesized underlying system impairments, the therapist performs further examination to gain additional information. The goal is to determine the underlying system impairments that are causing the functional limitation, and to prioritize them as a basis for developing an effective treatment plan.

For example, lack of tibial progression over the foot in stance could be due to limited ankle ROM (musculoskeletal system), or to insufficient hip extensor activity, allowing the pelvis to remain posterior to the foot during stance. In addition, the patient's fear (emotional system)and previous learning of a gait pattern based on use of a cane placed ahead of him, may bias the hip extensors to be stretched and therefore even more difficult to activate (neuromotor system) in the patient's normal standing and walking posture. Although the problem of knee hyperextension is rarely caused by one single system impairment, careful analysis and prioritizing will enhance the effectiveness of available treatment time.

Systems that most commonly affect control of the knee in gait include: neuro-motor system, musculoskeletal system, sensory-perceptual system, as well as emotional factors such as fear of falling. The following are samples of underlying impairments in various systems that can cause knee hyperextension in gait.

Neuro-Motor System

The individual recovering from a stroke often has problems with activation, graded control, balance and timing of muscle activation. These problems can affect knee control directly or indirectly.

Direct influences may include:

- Quads activity excessive and/or not matched by hamstring activity
- Difficulty grading and/or “turning off” the quads, especially in late stance when knee flexion is desired
- Difficulty coordinating and timing activity of knee flexors and extensors, while dynamically controlling rotational forces, and at the same time correctly activating muscle groups above and below the knee – to maintain balance (center of mass over base of support) while moving through space

Indirect influences may include:

- Insufficient dorsiflexion / plantarflexion activity to control the position of the tibia over the foot
- Insufficient hip extensor and flexor activity resulting in the hip “falling” backward into hip flexion, or use of anterior hip stability provided by hanging forward on the iliofemoral ligament. (See Picture 3).
- Faulty posture and movement control more proximally, with malalignment of body segments, resulting in the line of gravity passing anterior to the knee joint forcing the knee posteriorly
- Insufficient control of complex rotational forces. Rotations throughout the lower extremity are complex, and insufficient control in any part of the kinetic chain will affect the patient’s ability to control the knee

Musculoskeletal System

Musculoskeletal system problems can be preexisting or secondary. Often faulty length tension relationships among muscle groups result from the neuromotor system problems described above. Muscles that are overactive become tight, and less active muscles become over-lengthened and weak.

In addition to problems with the balance of muscle action between flexors and extensors, excessive activation of hip adductors or other unbalanced forces can result in faulty proximal alignment. These forces alter the axes of hip motion and produce forces at the hip that affect the knee (e.g. hip adductors become hip flexors and internal rotators when the hip is flexed). The effect of faulty hip joint alignment on knee function is probably under-recognized and inadequately addressed by therapists.

Sensory Perceptual System

Lack of awareness of the position and movement of the knee is an obvious limitation to the effective use of the knee during gait and a frequent cause of knee hyperextension. For patients with perceptual system impairments, problems with control of the knee may be

related to lack of awareness of the relationship of the parts of the body to each other, the body's orientation in space, etc.

Emotional Factors and Fear

Ambulation requires precise motor control coordinated with integrity of all other body systems. An individual may adopt a movement pattern, such as excessive "locking" of the knee due to heightened awareness and fear (e.g. knowing they can't feel the affected leg, wanting to make certain it supports them, or due to a past experience of falling).

EVALUATION AND TREATMENT PLANNING

As you continue the examination and evaluation, weigh the benefits and limitations of the patient's use of various movement patterns, prioritize the factors contributing to the functional gait limitations, and formulate a treatment plan with short and long term goals. Ongoing examination and evaluation in order to modify and enhance treatment effectiveness continues as an essential aspect of the NDT approach.

Developing Treatment Strategies

Treatment strategies are developed to remediate the problems identified in examination and evaluation. They are composed of various elements including: the desired activity or movement of the patient, the desired outcome in relation to impaired systems within the individual, and the position and handling provided by the therapist. Treatment strategies have a starting point; they evolve and are modified as the session progresses based on effectiveness of the intervention.

Treatment strategies address the following problems, identified at various levels, either individually or in combination:

- System impairments
- Posture and movement components
- Functional gait (Howle 2002)

Within a treatment session, there is a logical progression of treatment strategies. Within a session, it is common to begin with strategies that more directly target critical system impairments, then incorporate gains achieved into strategies to address posture and movement components, and conclude the session working on functional gait. However, the progression is not always linear, since it depends on the patient's performance and the therapist's continued assessment and thought process as the session progresses.

The following treatment strategies provide examples of treatment activities and rationale.

Treatment Strategies for System Impairments

Neuromotor System

Decide whether you can work directly on the neuromotor problem identified in the examination, and whether this is a high priority for treatment. Neuromotor system impairments can include: spasticity, impaired muscle activation (excessive coactivation, ineffective muscle synergies, and excessive overflow), and impaired motor execution (problems with scaling, timing and sequencing of muscle forces (Howle 2002).

- For a lower level patient, half-bridging might be used with facilitation to teach the patient to activate the hip extensors, rotate the affected side of the pelvis forward using hip joint motion (relative hip extension, abduction, and external rotation) while keeping the foot on the surface. This complex pattern requires dynamic interaction of knee flexors and extensors to stabilize the knee position over the foot while other parts of the body are moving.
- To address graded control in a more functional position, partial sit to stand may be used as a treatment activity. Facilitation is provided to assist the individual to learn dynamic mobility at the ankle as the body moves over the foot, then to learn gradations and timing of hip and knee extension and flexion in combination with learning to manage the center of mass over the feet. (See Picture 4).
- Control of rotational forces at the knee is essential to the development of controlled knee stability. In the stand to sit activity, the patient can slightly turn or “scoot” sideways before the controlled descent to sitting. Facilitation of correct medial-lateral position of the knee (over the foot) is essential for re-education of knee control.
- In the upright position, single limb stance with variations can be used to provide the demand necessary to facilitate activation of affected LE muscles. Progression toward single limb stance may begin with symmetrical standing, then progress to standing with weight shifted

toward the affected side, and finally with small wiggles or steps with the stronger leg to increase weight-bearing on the affected LE. Alignment of the affected leg (hip, knee and ankle) is critical for correct activation, as is the choice of patterns used to maintain the body mass over the stance foot. Facilitation is complex, since some movement (rather than "holding) is needed to stimulate dynamic activation of the leg, and the hip and knee must be kept from end ranges of hip extension, hip adduction, and knee extension or the patient will "hang" on the ligaments. (See Picture 5.)

- High level patients may benefit from facilitation while working on a stair-stepper or other similar device. Facilitation is critical, including keeping the body mass symmetrical or slightly toward the affected side to increase demand, and facilitating correct timing of the components of the flexion and extension patterns.

Picture 4: Sit to stand. The therapist facilitates effective forward weight shift while assisting optimal medial/lateral positioning of the patient's center of mass. In this situation, correct movement of the tibia over the foot can be facilitated by the therapist's knees. (Optional – weight bearing through the affected arm, when it can be managed without losing alignment of the lower extremity joints and correct distribution of the center of mass, helps to facilitate neuromotor activation throughout the kinetic chain.) **Picture 5:** Stance-stepping. The patient is facilitated to control the LE in active / dynamic alignment while performing a variety of activities with the stronger LE.

Excessive lateral shift of the pelvis is prevented, and the upper body center of mass is aligned over the stance leg to correctly distribute the line of force through the stance leg.

Musculoskeletal System

Problems here are often secondary or preexisting. They may be easy to remediate during a session, but carryover may be difficult, since the causes (often neuromotor system impairments) may persist.

Some considerations for treatment include:

- Maintain/regain length and mobility of the hip joint and hamstrings (especially the medial hamstrings).
  • Maintain/regain length of ankle and foot muscles. Shortness in the ankle plantar flexors is a common mechanical reason for knee hyperextension.
- Combine musculoskeletal treatment with reeducation: Employ activities that stimulate less active muscles in the desired ranges with the stronger/shorter muscles lengthened and at a disadvantage. Dynamic activities in partial squat position with well-aligned rotations and weight shift, as described above, can be used to lengthen stronger muscles and activate weaker ones simultaneously, maximizing the effectiveness and carryover of treatment activities.
- An activity that can be very effective in treatment or modified as a home activity for some patients, is lateral weight shifts in standing with a wide base of support, with legs abducted to near end range and knees straight. Lateral weight shifts occur in the coronal plane, consisting of hip abduction and adduction combined with upward and downward list or tilt of the pelvis. This motion provides an effective stretch to the adductors and hamstrings. By lengthening muscles crossing the hip and knee and realigning the hip joint, the unbalanced forces on the knee can be minimized, providing the individual with the opportunity to work on knee control more easily and directly. In this activity, the knee may need to be directly aligned, extended, and stabilized by the therapist, at least initially, due to the strong rotational forces that may be present.

Sensory System

- Recognize the significance of sensory loss. Patients without sensation may be able to eventually control the knee in slow walking by paying attention to other cues of knee position, but may not be able to maintain this attention for finely graded knee control in fast gait or in function when paying attention to other tasks.

- The therapist provides enhanced sensory input through enhanced weight-bearing to increase sensory awareness and interpretation.
- In addition, he/she attempts to predict the individual's long-term function and consequences. This information might impact the other patient management decisions (e.g. style of AFO, or ankle-foot orthosis, strength of control, etc.)
- Taping can be used as an adjunct for teaching the patient that the knee should be "straight but not locked" in mid-stance and the beginning of late stance. It can be a useful way to increase sensory feedback and provide reeducation of more effective timing and sequencing of muscle activity. In addition, faulty rotational components can be corrected through taping for enhanced reeducation.

Psychological / Emotional System

Patients may become comfortable with knee hyperextension in gait for many reasons, including the clear sense of stability provided by the locked knee. In attempting to remediate this gait deviation, strategies may need to address the patient's apprehension or fear. Modifications of treatment strategies might include:

- Positioning the patient with his/her back against a wall to assist with alignment and a sense of correct posture, but also to provide posterior stability as the patient attempts new ways to move, such as wall slide with concurrent hip and knee flexion and weight on the affected LE.
- You may provide stability as needed anteriorly and/or posteriorly with your knees while sitting facing the patient's side, allowing the patient to safely experiment with new and unfamiliar movement patterns.
- Working with the patient standing in front of the treatment mat may also provide safely and a sense of security, and may be a more effective alternative to the use of a support or assistive device with the upper extremity(ies), which will alter the biomechanics and control required for a standing or stepping activity.

TREATMENT STRATEGIES FOR FAULTY POSTURE AND MOVEMENT COMPONENTS

The individual recovering from a stroke faces challenges to his or her motor control in all activities. The patient must learn to control the body mass and body segments in a way to optimize the knee's ability to control the forces involved in standing and walking.

- While it is difficult for patients to achieve active and dynamic knee extension, it is deleterious to the patient's overall biomechanics and motor control to allow the patient learn to

walk with excessive knee flexion. Facilitated standing weight shift and stepping with the stronger LE is possible as described above. Knee control is provided and supported as needed by the therapist as the individual learns lateral weight shift in preparation for the step, and the correct forward-diagonal and backward –diagonal weight shifts associated with stepping and weight transfer.

- Train the leg in single leg stance, supported as necessary. Body alignment must be maintained, and activities that require active mobility of the hip and knee through various ranges will help to prepare the leg for the demands of gait. The activity must be effortful enough and sustained enough to train the types of muscle contraction that will be needed during ambulation. Consider using a wall in back of the individual for "support" since use of the UE's for support will alter the biomechanics of the task and reduce the effectiveness of the activity.
- Many of the previous treatment strategies for addressing impairments also can be used to address posture and movement components. Your handling may change, based on the goal of the strategy. This adaptation of treatment strategy is often a part of the treatment session progression, with the therapist initially providing specific and sometimes firm input, then changing handling to assist with posture and movement components such as weight shift or overall body alignment and stability as the patient takes over more of the control. Strategies at this point often address several problems at once. For example, an activity such as facilitated forward stepping with the unaffected LE might:
    - stretch the ankle plantar flexors (musculoskeletal system)
    - activate the hip extensors (neuromotor system), and
    - train LE activation with the leg behind the body as needed for late stance (posture and movement component)

TREATMENT STRATEGIES FOR FUNCTIONAL GAIT

- During gait, facilitate weight shift of the body via hip extension forward over the affected foot in mid to late stance. Facilitation is provided posteriorly at the hip joint (not the lumbar spine) for precise and correct cueing. Often patients do not take a long step with the stronger LE because of inadequate ability to support themselves while continuing to move forward in stance on the affected side. Facilitation and/or support may need to be provided laterally, posteriorly, and sometimes anteriorly to prevent inactive "hanging" at the hip.
- Facilitate alignment and stability of the trunk in all planes, with

movement occurring at the hip joint during progression in stance.

- Patients may need to be cued or facilitated to use less effort in late stance and early swing, since “stiffening” the LE in anticipation of swing may lead to a stiff and hyperextended leg in stance. This is a habit pattern learned by many patients as they and their therapists address effort and energy toward getting the leg to move forward. In normal swing, there is very little muscle activity and most of it is eccentric. The focus of gait training, starting from very early in the individual’s recovery, needs to be on stability during stance, and then “letting go” to allow for swing (assisted early on, as necessary).
- Emphasize the big and critical movement components of gait, including activation of the LE in stance, with the body stable and upright over a dynamic leg, and hip extension and ankle dorsiflexion acting as the axes for forward progression. Don’t lose sight of the big picture as you and the patient try to address the details. (See Picture 6.)
- Once you have addressed the “big picture” aspects of movement during gait, guide and cue the knee to be “straight but not locked” in mid stance and the beginning of late stance. Wobbling of the knee in stance, while disconcerting to the patient, is often a good sign that the individual is “on the edge” trying to activate balanced flexion and extension with the rest of the body aligned

Picture 6: Gait facilitation. This patient is facilitated in functional gait for a few steps after facilitation of stance control and stretch of LE joints and soft tissue limitations through facilitated weight-bearing. Her AFO will be replaced for ambulation of longer distances to prevent development and use of a compensatory swing pattern. She will also be encouraged to resume an upright position of upper trunk and head once she is assured that right lower extremity will adequately support her, since she has significant sensory loss.

correctly.

- Anticipate and limit substitution of compensatory strategies. Patients who are working hard to learn control will often substitute one compensatory pattern for another. In attempting to prevent rotation of the pelvis backward on the affected side and the hip flexion that results, the alert patient may develop a pattern of excessive forward weight shift or rotation of the affected side of the pelvis, thereby locking the hip by “hanging” passively in extension. This pattern can contribute to knee hyperextension in the same manner that a paraplegic walks with passively “locked” hip and knee extension.
- Backward walking is less automatic for most patients, and is a good way to facilitate active control of knee flexion and extension with hip extension. This movement pattern may be more amenable to facilitation, since it has not usually been as strongly reinforced through daily use.

OVERALL CONSIDERATIONS AND USE OF ADJUNCTS

- An AFO may be needed to facilitate heel strike and reduce active or passive plantarflexion that contributes to knee hyperextension. An AFO that allows free dorsiflexion of the tibia over the foot in late stance is usually preferred. In addition, if strong rotational forces have developed or are developing through the LE, an AFO that wraps around the ankle (Cascade style) may be necessary. Ankle inversion with external rotation of the tibia is usually associated with strong internal rotation of the femur and a hip that is unstable or has strong unbalanced activation. Providing ankle control and stability in correct alignment, especially early on, may provide needed assist so that more effective reeducation of the hip can take place.
- An AFO may be needed to prevent an ankle sprain in the individual who cannot sense position of the ankle. A stabilized ankle in neutral alignment may also allow the individual to use a more effective lateral weight shift for stance, with the line of gravity passing down through the foot for stance stability, rather than falling lateral to the inverted foot and contributing to additional inversion and instability.
- Train gait without an assistive device (or with support that varies and/or keeps the shoulders over the pelvis), so that the individual learns to control his or her mass over the base of support. Consistent use of an assistive device teaches the individual to control the body mass over a base of support that includes the assistive device. Assistive devices that are used ahead of the body will position the hip in flexion, often making it impossible for the individual with motor control limitations to prevent knee hyperextension.

- Body Weight Supported Gait Training may be an effective adjunct, providing the opportunity for you to facilitate the desired components as outlined above, and decreasing the patient's use of an upper extremity assistive device and the associated incorrect movement patterns while relearning to walk.

Don't forget to keep an eye on the "big picture." Use your "zoom lens" to alternate looking very specifically at the details of your patient's problem at the knee, while integrating that information with ongoing assessment of his/her current function, any pain complaints, safety issues, decisions regarding the use of adjuncts, the need to optimize the effectiveness of individual treatment sessions, issues related to carryover, short and long term functional goals, and anticipated function post discharge.

Monica Diamond, MS, PT, is Rehab Services Clinical Educator at Columbia St. Mary's / Sacred Heart Rehabilitation Institute in Milwaukee, Wisconsin. She is an NDTA™ Coordinator Instructor and a member of the International Bobath Instructors Training Association (IBITA). She can be reached at DiamondPT@aol.com.

REFERENCES

Howle, Janet M., with the NDTA™ Instructors Group Theory Committee. 2002. Neuro-Developmental Treatment Approach: Theoretical Foundations and Principles of Clinical Practice. Neuro-Developmental Treatment Association.

Cascade Dafo, Inc., Ferndale, WA. www.dafo.com

Neumann, Donald A. 2002. Kinesiology of the Musculoskeletal System: Foundations for Physical Rehabilitation; Mosby; St. Louis.