2001

Examination and Management of Spasticity and Weakness

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ABSTRACT

In this paper information pertaining to the teaching, within a MS physical therapy curriculum, of the concepts of "spasticity" and "weakness" is presented. These concepts are taught in 2 required and 1 elective course, which span the 2-year program. Students are expected to develop both physical mastery of the skills necessary to treat, confidently and efficiently, as well as the ability to critically analyze each examination and intervention procedure. Four questions are used to guide the students as they learn the material pertaining to examination and intervention. (1) What is the theoretical rationale? (2) Is there basic science evidence that is consistent with the theoretical premise? (3) Are clinical efficacy data available and how consistent are these data between studies? (4) Could the examinations and interventions that were used in controlled published studies realistically be performed by therapists in a clinical setting? Included in the paper are a course overview, description of the course contents, required texts, definitions, the neurologic exam, examination and interventions for spasticity, and examination and interventions for strength.

INTRODUCTION

The purpose of this paper is to share information pertaining to the teaching (within a 2-year MS physical therapy curriculum) of the concepts of *spasticity* and *weakness.*" These concepts are taught in 2 required and 1 elective course, which span the 2-year program. The courses are: Neuroscience (2nd semester of the 1st year [required]), Neurological Rehabilitation (1st semester of the 2nd year [required]) and Special Topic Seminar (Advanced Issues in Motor Control [elective]). The paper will include an overview, description of the course contents, required texts, definitions, the neurologic exam, examination, and interventions for spasticity and examination and interventions for strength.

OVERVIEW

It is important for students and future therapists to establish core scientific knowledge of the mechanisms guiding human movement. Didactic lectures in the neurosciences build on previous courses in physiology, anatomy, kinesiology, and biomechanics in order to provide this foundation. Following the acquisition of a sufficient knowledge base there is a progression, in subsequent clinical courses, such as Neurological Rehabilitation, to a more problem-oriented teaching approach. For example, a clinical problem will be presented (eg, there is stiffness in a muscle following stroke) and the students will be asked to problem solve why this might be. By this point in the students' curriculum they would have completed the Neuroscience course and be familiar with the pathophysiology and clinical presentation of an individual with a cerebrovascular accident. A similar approach is used to discuss assessment and treatment methods.

It is expected that students will achieve the following: (1) physical mastery of the skills necessary to treat, confidently and efficiently, patients presenting with a wide range of disabilities and; (2) the ability to critically analyze each assessment and treatment procedure. Students are required to evaluate each examination and intervention approach by determining the following:

1. What is the theoretical rationale?
2. Is there basic science evidence that is consistent with the theoretical premise?
3. Are clinical efficacy data available and how consistent are these data between studies?
4. Could the examinations/interventions used in controlled published studies realistically be performed by therapists in a clinical setting?

Classroom discussions of examination and intervention options generally follow a patient's hypothetical chronological progression from an initial cerebrovascular event and diagnosis through rehabilitation and various phases of recovery. Lectures, labs, and discussions begin with acute management and bedside activities for the very involved patient. Lectures and labs present a spectrum of disabilities including rehabilitation procedures for enhanced fine motor control of the minimally involved patient.

Interventions that are often considered to be on the "fringe," or that have been popularized by continuing education offerings, are similarly discussed and evaluated. Craniosacral therapy, "release" techniques, and patterning are examples. The Neurological Rehabilitation course also includes discussions of current basic and clinical science research related to the development of new treatment approaches for neurological disorders.

Required Texts

Five textbooks are used to supplement class presentation for the Neuroscience and Neurological Rehabilitation courses. *The Human Brain*[1] by John Nolte is the

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core textbook used for the Neuroscience course. Structure of the *Human Brain*[2] by Stephen J DeArmond, et al is used as an atlas during laboratories on brain dissection. Early chapters of *The Neuroscience of Human Movement*[3] by Charles Leonard are assigned to students to read prior to and during the early portions of the Neuroscience course. Later chapters are assigned during the Neurological Rehabilitation course. The later chapters use a "systems" approach to presenting material by discussing how various CNS pathways and mechanisms interact to accomplish a particular motor behavior. This book and Dr. Nolan's book are intended to bridge basic and clinical neurosciences. Michael Nolan's book, *Introduction to the Neurological Examination*[4] is used at the end of the Neuroscience course and beginning of the Neurological Rehabilitation course to provide students with a reference for the neurological examination. The book provides brief explanations of the neurological mechanisms underlying the various tests and also the mechanics of performance. *Neurological Rehabilitation*[5] by Darcy Umphred is used as a reference text for the Neurological Rehabilitation course.

The required texts serve as adjuncts to the lectures and labs. Books are chosen based on their ability to assist and engage students as well as making a contribution to their professional library. Students are not tested directly on text material.

Course Content

Specific course content pertaining to spasticity and paresis will be detailed below. The courses will be outlined and then greater detail will be provided on the definitions, clinical exam, and interventions with an emphasis on the concepts of spasticity and weakness. The Neuroscience course presents the pathophysiology and associated impairments of terms such as 'spasticity.' The Neurological Rehabilitation course reviews pathophysiology but emphasizes relationships among impairments, functional limitations, and disability.

Neuroscience Course (4 credit hours)

This course introduces the:

1. Terms such as "reflex" and mechanisms subserving various reflexes and motor behaviors (eg, stretch, Flexor Reflex Afferents [FRAs], and Central Pattern Generators [CPGs]) via didactic lecture.
2. Mechanisms of muscle contraction and inhibition (including supraspinal contributions).
3. Consequences of having the mechanisms disrupted by disease or injury.
4. Terms "spasticity" and the concept of a "spastic condition" and positive and negative signs.
5. Etiology of Upper Motor Neuron (UMN) disorders such as Spinal Cord Injury (SCI) and Multiple Sclerosis (MS), including the pathology, impairment, disability
6. Relationship between spasticity, paresis and motor control issues.
7. Neurological examination, including clinical assessment of spasticity and muscle strength (labs and lectures). The mechanisms and pathways underlying each test are emphasized.

Neurological Rehabilitation Course includes (5 credit hours)

1. A review of a typical adult neurological examination, which was introduced in Neuroscience and is taught here with a different emphasis, with attention to mechanisms being tested, and significance of abnormal findings (lab). Emphasis is on gaining proficiency in administering the examination.
2. Examination of patients and generation of problem lists and proposed interventions. For some students this is their first hands-on experience with spasticity. These patient experiences continue throughout the semester (generally 1 per week).
3. A review of neurological mechanisms subserving motor control and neuropathology.
4. Definitions of tone, compliance, stiffness, spastic condition, spasticity, paresis.
5. Practice with clinical assessment tools such as the Ashworth, Ely, drop-knee, strength tests, Myotonometer testing, functional outcomes).
6. Opportunities to review and summarize available research (theoretical, experimental, clinical).This exposes the disparities between what is known of the mechanisms underlying spasticity and how we test clinically for spasticity.[6-10]
7. Practice with research assessment tools (eg, manipulandums, reflex threshold testing, pendulum, EMG, and an evaluation of problems applying them to clinical use).
8. Interventions
    a. brief historical review (Denny-Brown, Sherrington, Brunnstrom, Bobath);
    b. relationship between spasticity, paresis and motor control and implications for treatment (eg, changing Ensory parameters will affect motor control);
    c. discussion of available and typical treatments;
    d. discussion of atypical or "fringe" treatment approaches;
    e. each treatment is analyzed for evidence-based support from both theoretical perspective and clinical evidence; and
    f. future trends and directions.
9. Disablement Model (Nagi)
10. A presentation about the *Guide for Physical Therapist Practice* as it relates to the neurological patient and suggestions for its use.

Definitions:

Clinical definitions of spasticity and associated muscle characteristics are somewhat confusing and controversial. The traditional clinical tests used to assess spastic paresis (spasticity; spastic condition) do not assess adequately what is now known regarding the contributory mechanisms. The lack of precise definitions has contributed to the difficulties associated with clinical examination and quantification. Considerable class time is spent discussing these issues and in the importance of establishing operational definitions. Following are the definitions provided to students.

Muscle strength: The amount of force (torque) that can be generated by muscle activity.[4]

Muscle compliance: The amount that a muscle can be stretched. Compliance is expressed as the amount of change in length per unit of force used to stretch the muscle (the inverse of muscle stiffness). It is assumed that the neural drive remains constant during measurements of muscle compliance.[11]

Muscle stiffness: Magnitude of force necessary to cause tissue displacement.[11]

Muscle tone: Firmness of the tissue. Resistance to passive stretch that reflects the relative influences of mechanical-elastic characteristics and neural drive to the muscle. [12,13]

Spasticity: A motor disorder characterized by velocity-dependent hypertonia and hyperactive tendon reflexes. Some definitions include clonus in addition to hypertonia and hyperactive tendon reflexes.[14-16]

Spastic condition (spastic paresis): The constellation of positive and negative signs and symptoms associated with spasticity.[10,13,16]

Positive signs include:
- hyperreflexia (increased DTRs, clonus, mass reflex responses [FRAs])
- spasticity
- pathological reflexes (eg, Babinski, Hoffman's)

Negative signs include:
- muscle paresis
- loss of fractionation of movement
- abnormal motor unit recruitment
- disrupted muscle synergies or obligatory synergies
- loss of coordination and dexterity
- spatial and temporal movement abnormalities

Spastic Condition (Generalized Principles)

1. Mechanisms of spasticity differ among various CNS disorders[7,17-19]
2. Muscle stiffness (hypertonia) has neural and non-neural components[20-22]
3. Muscle spindle and dorsal roots appear to be functioning normally[23,24]
4. Alpha motor neurons are partially depolarized following UMN damage[10,23]
5. Most afferent input will accentuate already depolarized alpha motor neuron pools[25,26]
6. Disruptions in motor unit recruitment (e.g. asynchronous recruitment)[27-29]
7. Evidence of disruption of presynaptic and interneuronal mechanisms[30-32]
8. Hypertonia and spasticity are not due solely to abnormal stretch reflexes[19,22]
9. The fact that we assess tone by resistance to passive stretch does not indicate that the functional significance of this testing is limited to the stretch reflex

Neurological Examination

The neurological examination is a crucial component in a student's preparation for practice. A high level of competency is expected. Students, therefore, are given ample exposure and time to practice throughout the curriculum. Examination procedures vary dependent on the patient population. Following is a typical outline provided to students for an adult neurological examination.

Principles of the Adult Neurological Examination

Deep Tendon Reflexes (DTRs)

Muscle Tone
- Ashworth- resistance to passive stretch
- Other more quantifiable measures if clinically realistic (eg, Myotonometer testing; Compliance Meters)
- Spasticity (increased tone, accentuated DTRs)
- Co-contraction with movement?

Special Tests for Involvement of Corticospinal Tract (CST)
- Babinski
- Hoffman's

Cranial Nerves Testing

Sensory Testing
- (pp, light touch, 2 pt. discrimination, stereognosis, pain, proprioception)
- Check for asymmetries and hemianopsias

Cerebellar Testing
- Finger to Nose
- Rhomberg
- Rapid Alternating Movements (RAMs)
- Heel/Shin
- Heel/Toe Walking
- Walk Eyes Open and Closed

Range of Motion (ROM)
- Active first and then passive assessment

Motor Testing
- Posture
- Associated reactions with change of position or effort
- Strength
- Atrophy
- Presence of synergies during voluntary movement
- Involuntary movements (resting vs. movement induced tremor)
- UE target acquisition accuracy

Gait Assessment

Motor Planning (Praxis)

Spatial Deficits

ADL and Assistive Devices

Should be functional and related to stage of recovery

Relate ADL assessment to what patient will encounter in their residence and community

Note amount of energy required for ADL

Physiological Cost Index (PCI) and other clinical indices

$$PCI = \frac{\text{Exercise Heart Rate (bpm)} - \text{Resting Heart Rate (bpm)}}{\text{Speed Distance Ambulated (meters/min)}}$$

Movement Quality

Fugl-Meyer

Prognostic Factors[33-36]

Examination of Spasticity

Several assessment approaches are available to prepare the student to be a clinician and a researcher. Students receive lectures and labs, during the Neurological Rehabilitation course, that present each of the following methodologies. The goal is for the limitations of clinical tests (eg, Ashworth, Kotke) to become apparent to students. The benefits, problems, and limitations associated with tests commonly used in a research laboratory setting should also become equally apparent. New techniques and technologies are presented. Below are a list of the tests and comments that are presented to students.

Ashworth (or modified Ashworth) Scale: Is a subjective, ordinal scale yet it remains "Gold Standard" by which other tests are validated. Problems include clustering, lack of an ability to assess small changes, and poor inter-rater reliability.

Ely Test: A subjective clinical test of hip flexor spasticity and contracture.

Kotke or Thomas Test: A subjective hip flexion contracture test.

Isokinetic Testing (Pendulum tests)

-Relative angle of reversal

-Threshold angle

Attempts to quantify pendulum testing have resulted in complicated mathematical formulas, often do not account for leg length or mass differences, and test can only be applied to LE. Good research tool.

EMG Response to Stretch via Manipulandum: Establishes threshold angle for various velocities of stretch. Excellent research tool but makes false assumption that stretch reflex is sole determinant of spasticity or limb stiffness.

H-Reflex Testing (H/M ratios): Excellent research tool but findings do not always correlate well to clinical assessment of spasticity severity and testing involves a very complicated set-up.

Pathophysiological Profiles of Movement: Are designed to quantify the degree to which paresis, spasticity, muscle cocontraction, and non-neural muscle changes contribute to a disability. Requires EMG, torque-meter, and motion analysis equipment. Excellent idea but equipment and labor involved discourage clinical use.

Myotonometer: A patented* (Leonard CT, Mikhailenok EL. Apparatus for Measuring Muscle Tone. 09/295277(6063044). 5-16-2000. 4-20-1999) handheld computerized electronic device that provides quantitative measurements of muscle stiffness (tone/compliance) by measuring force and displacement of muscle tissue. Correlates well to the modified Ashworth scale yet is able to detect smaller changes in tone and can be applied to any muscle (postural or extremity). Clinical utility has not yet been established.

Interventions for Spasticity:

Students are provided with several strategies to manage the spastic condition. The American Neurological Association pyramid of preferred treatment approaches is presented (Figure 1).

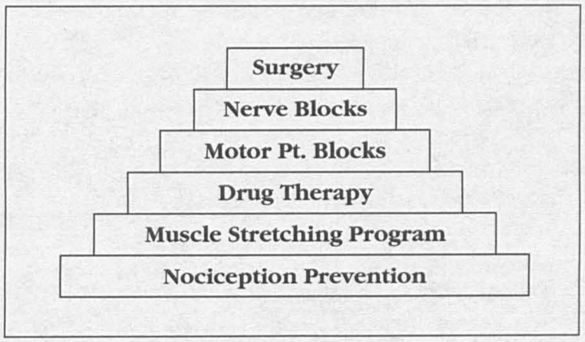

Figure 1.

The following interventions are discussed and analyzed with students using the theoretical and practical parameters presented previously. The relationships between muscle tone, motor control, and motor learning are emphasized. For instance, how will motor control be affected if a patient experiences pain, and subsequent increases in muscle tone, following the fitting of an orthosis? How will motor learning be affected if you change assistive devices? How will altering muscle tone (stiffness) via a treatment intervention potentially affect motor control and learning?

Prevention of nociception[37]

Stretching[38-41]

Serial casting/Splinting[42,43]

Positioning[44,45]

Pressure over spastic muscle or nerve[46]

Electrical Stimulation[47]

TENS[48,49]

FES[50-52]

Activity (repetitive use)[38,53,54]
Biofeedback[38,55]
Mental Imagery[56]
Robotics[57]
Combined pharmacological and physical therapies
(eg, clonodine and treadmill locomotion)[58]
Constraint Induced Therapy[59-61]
Treadmill locomotion[62]
Virtual environments[63,64]
Computer assisted motor learning[61,65]

Pharmacological Interventions[66-68]
Surgical Interventions

Examination of Strength:

The problems with assessing the strength of individuals with neurological involvement are discussed (eg, spasticity masking weakness, cognitive factors). The procedures listed below are those offered to students as the preferred alternatives. Students have received training in manual muscle testing, dynamometry, EMG, and isokinetic testing prior to the Neurological Rehabilitation course. Myotonometer, and functional strength testing are introduced via lab sessions. All measurement techniques are placed in context of assessing the neurological patient. At the conclusion of the course, students should be able to perform a strength assessment of a neurologically involved patient and provide a rationale for why they chose a particular assessment tool.

Isometric Muscle Testing
Hand-held Dynamometer
Surface EMG
Myotonometer,
Isokinetic Testing
Functional Strength Testing (eg, sit-to-stand, stairs...)

Strength Training and Related Issues:

The importance of muscle strength and aerobic capabilities to improving functional outcomes is discussed. Research showing functional gains related to strength or aerobic gains is presented.

Aerobic training[69,70]
Strength training[71]
Functional activities[72]
Motor control[72,73]
Motor learning[3]

Student Performance Outcomes:

Our department assesses the curriculum on a yearly basis. New graduate assessment forms are sent to clinical instructors and employers of our students. Instructors and employers consistently rate our students knowledge in neurology as high to very high. Students score the highest on clinical examination, scientific knowledge, and clinical decision-making. Students score lowest on hands-on patient skills and documentation.

SUMMARY

The mechanisms that contribute to spasticity and paresis resulting from various neurological diseases and injuries are not completely known. The teaching of these concepts, therefore, represents a unique challenge. Students need to be equipped with the most recent knowledge pertaining to the neural and non-neural mechanisms that contribute to disability. They also need to be equipped with clinically useful tools to assess and treat their patients in an efficient and timely manner. Often accuracy of measurement and clinical utility are in conflict. Resolution of these conflicts requires clinical decision-making abilities. These abilities will evolve from a solid foundation in scientific principles and clinical experience.

Evidence-based practice presents an ongoing challenge to clinicians. Clinicians should be encouraged to always assess treatments for scientific validity and clinical efficacy. But, they should not be discouraged from experimenting with new methods. Neurological rehabilitation, for many reasons, has entered a period of rapid change. New assessment tools and treatment techniques will be developed after the student graduates. If the student has received a strong scientific foundation and has been schooled in clinical observational skills, they will be in a position to critically analyze newer methods and implement those most beneficial to their patients and clients.

ACKNOWLEDGEMENTS

I would like to thank Steven Fehrer, PhD, PT for his contributions to curriculum development at The University of Montana and for his review of this manuscript. I would also like to thank Judith Deutsch, PhD, PT for her review and helpful suggestions.

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