

Proprioceptive Neuromuscular Facilitation

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Proprioceptive Neuromuscular Facilitation (PNF) is a dynamic approach to the evaluation and treatment of neuromusculoskeletal dysfunction with particular emphasis on the trunk. Over the past couple of decades substantial progress has been made in the conservative care of spinal problems.¹⁻⁵ The shift towards evaluating and treating them from a functional or neuromuscular perspective enhances and complements the symptomatic and structural approaches.⁶⁻¹⁴ A functional or neuromuscular approach looks beyond the classical diagnosis, identifying their habitual patterns of posture and movement; their dynamic strength, flexibility, and coordination; and the specific muscle recruitment and motor control of the symptomatic region, as well as contributing factors in the patients' environment.

PNF applies neurophysiological principles of the sensory/motor system to manual evaluation and treatment of neuromuscular skeletal dysfunctions. PNF provides the therapist with an efficient means for evaluating and treating neuromuscular and structural dysfunctions.¹⁵⁻¹⁹

Structural dysfunctions (myofascial and articular hyper- and hypomobilities) affect the body's capacity to assume and perform optimal postures and motions and often are associated with symptoms.^{2,5,15,20-22}

Neuromuscular dysfunctions (inability to coordinate and efficiently perform purposeful

movements) cause repetitive, abnormal, and stressful usage of the articular and myofascial system, often precipitating structural dysfunctions and symptoms.^{3,6,12,19,23,24}

The goal of the PNF approach is to facilitate an optimal structural and neuromuscular state. This helps to reduce symptoms, to improve the distribution of forces through the symptomatic region, and to reduce the inherent functional stresses caused by poor neuromuscular control.^{15,19,23,24}

The principles and procedures of PNF are especially effective when integrated with appropriate use of joint and soft tissue mobilization techniques. The basic philosophy and principles of PNF can be universally integrated into any treatment approach, since the foundation is the evaluation and treatment of posture and movement. The utilization of PNF for spinal dysfunction is enhanced by a working knowledge of arthrokinematics, neurophysiology, and possible pathomechanics of the spine.

THE EVOLUTION OF PNF

The PNF approach was developed by Herman Kabat, MD, and Margaret Knott, PT, (Fig. 11.1), during the 1940s and early 1950s, primarily as a method to treat patients with neurological dysfunctions.^{16,25,26} Dr. Kabat desired to offer more to the neurologically involved patient population than walkers and passive range of motion exercises. He



Figure 11.1. Margaret Knott, PT (December 18, 1978)—Devoted to her patients, dedicated to her students, and a pioneer in her profession.

searched the literature to uncover basic neurophysiological principles which could serve as the foundation for a more dynamic and functional approach. His studies led him to the works of Sherrington, Gellhorn, Coghill, Gesell, Hellebrandt, and others.^{15,17} These researchers identified that a muscle response could be influenced by resistance, stretch reflex, irradiation, and other proprioceptive input. Stimulated by his studies, Dr. Kabat searched for clinicians whose treatment approach could serve as a foundation for the clinical application of these neurophysiological principles. His search then led him to Sister Elizabeth Kenny, who was successfully using manual resistance and neurophysiological principles to facilitate active functional movement in polio patients.

Dr. Kabat, a physician who liked to physically work with his patients, began to put into action the knowledge he had acquired

through his research, along with the clinical knowledge he gained from watching Sister Kenny. His goal was to meet the needs of the neurological population by focusing on the reeducation of the patient's developmental postures and movements. He believed this approach facilitated the patient toward more efficient function and independence during ADL.¹⁶

The effectiveness of PNF evolved with its specificity. When Margaret Knott began to work with Dr. Kabat in the mid-40s, they focused their attention toward utilizing the concepts of resistance, stretch reflex, approximation, traction, and manual contact to the facilitation of efficient motor recruitment patterns. Their goal was to facilitate efficient responses in specific muscles and muscle groups. This commitment towards developing specificity laid the groundwork for the effectiveness of PNF as a broadly applicable manual therapy approach.

Regardless of the underlying pathology, evaluation and treatment of structural and neuromuscular dysfunctions depend upon an assessment of specific motor recruitment and control. The PNF approach offers the trained clinician tools to quickly and effectively evaluate these motor components. It builds on the concept that motor recruitment can be enhanced through appropriately utilized reflex and proprioceptive input. From this initial foundation, PNF continues to evolve to new levels of proficiency through clinical experience and scientific advances, but the initial concepts and principles developed by Kabat and Knott have withstood the test of time.

PHILOSOPHY

The philosophy of the PNF approach is based upon the premise that *all human beings have untapped existing potential*. Therefore, the role of the physical therapist is to identify dysfunctions and facilitate the patient's optimal physical capacity.^{10,15,17,27}

To facilitate the patient's optimal functional level and insure total involvement in the rehabilitation program the therapist must

develop effective rapport. An important aspect of developing rapport is to capitalize and place emphasis upon the individual's physical, mental, and emotional strengths, rather than his or her deficits. A person's strengths become the foundation from which reeducation and learning take place. Working from one's strengths, rather than one's deficits, tends to achieve success, not frustration—physically, mentally, emotionally, and spiritually.

Strengths are best utilized by mutually agreeing upon clear and attainable short- and long-term goals. These goals should be developed both from a thorough evaluation and the needs and desires of the patient. Based upon established goals, the treatment program is specifically designed to address the identified functional limitations.

When treating neuromuscular dysfunctions, complex motor patterns are reduced to their basic movement and developmental components. The emphasis is placed upon selective reeducation of individual motor elements, through developing the fundamental skills of trunk control, stability, and coordinated mobility. These basic motor skills are built upon by progressing to less stable postures and more complex functional activities. Each movement and posture learned is reinforced through repetition in an appropriately demanding and intense training program. This program may consist of manual treatment, a home program, an exercise class, and or a gym program. The intensity of the physical program is graded to meet the patient's specific strength and endurance needs for performing efficient postures and movements during daily activities.

PRINCIPLES

The principles of PNF are based upon sound neurophysiological and kinesiological principles and clinical experience.^{10,15} Each is an essential component of the approach and provides the basis for developing consistency throughout the evaluation and treatment process. Through applying these basic principles, the patient's postural responses, movement

patterns, strengths, and endurance can be assessed and enhanced.

Manual Contacts

The psychological effect of manual contact is well known.^{15,28,29} The comment "You are the first one to really touch me where it hurts" is frequently made after the initial evaluation by a manual medicine or therapy practitioner. The inherent responsibility of a manual therapist is to maximize the psychological benefit by establishing trust and cooperation without facilitating dependency.

The quality of touch influences the patient's confidence and the appropriateness of the motor response and relaxation. Therefore sensitivity and specificity should be utilized when applying a manual contact. The therapist should be consistent and specific with all manual contacts to allow for accurate evaluation, effective treatment, and continuous re-assessment.

On a physical level, manual contacts to the skin and deeper receptors influence neuromuscular responses.^{30,31} Through the use of appropriate and specific manual contacts, the therapist can influence and enhance the direction, strength, and coordination of a motor response. *Appropriate manual contacts are applied to the skin surface on the side to which the movement or stabilizing contraction is desired.*^{10,15} If inappropriate contacts are applied, the sensory input is confusing and affects the motor response. One testing for shoulder flexion strength to access the effectiveness of the applied manual techniques can distort the findings if consistent manual contact is not maintained during the pre and post treatment testing. Use of a lumbrical grip is the most effective means of applying appropriate manual contacts. This allows for a less compressive grip, while still facilitating specific unidirectional contact (Fig. 11.2).

Therapist Position and Body Mechanics

An essential aspect in applying appropriate manual contacts is the use of proper body position and mechanics.¹³ *The therapist needs*



Figure 11.2. Appropriate manual contact—utilizing a lumbrical grip.

to position his center of gravity and base of support in line with the direction of motion being resisted. This position allows the movement to occur either towards or away from the therapist, so that weight transference and acceptance can be coordinated and smooth. The therapist's total body and arm movement should equal the same excursion and reflect the same arc of motion as the body part being treated. The therapist's spine should remain in a neutral alignment with motion occurring primarily in the hips, legs, and arms (Fig. 11.3).

Appropriate manual contacts and body position provide resistance from the therapist's trunk rather than the upper extremities. Therefore, the arms can relax and better translate the resistance and evaluate the motor response. The slightest deviation from the use of appropriate position and body mechanics can alter the desired response and distort the therapist evaluation.^{10,13,15}

Appropriate Resistance

Appropriate resistance¹⁰ is the amount of resistance which facilitates the desired motor response through a smooth, coordinated, and optimal muscle contraction.¹⁵ Appropriate

and variable resistance is applied to an active contraction for two purposes.

- Initially, the resistance allows the therapist to evaluate the patient's motor response. Characteristics such as control, strength, initiation, stabilization, endurance, relaxation, and quality of contraction are effectively assessed when manual resistance is applied to the patient's contraction.^{10,15,19}
- If a dysfunction is identified in any of these characteristics, appropriate resistance applied in conjunction with various PNF techniques, facilitates the relearning and rehabilitation process.^{10,15,18}

During normal activity the neuromuscular system utilizes a variety of muscle contractions to meet the normal demands of efficient motor control.³² The patient's capacity to stabilize (isometric), as well as move (isotonic), can be specifically evaluated through manual resistance. The use of resistance allows the therapist to determine the patient's ability to selectively and efficiently perform and integrate each of these contractions. Identified dysfunctions are specifically treated to facilitate optimal function.

The kinesiological definitions of isometric and isotonic contractions vary within the lit-



Figure 11.3. Proper therapist body position and body mechanics—promotes smooth and coordinated movements.

erature. We have chosen to define these terms to correspond with “functional evaluation and treatment” represented by the approach of PNF.

Isometric Contractions. The traditional definition of an isometric contraction is one in which “the external force is equal to the internal force developed by the muscle and no external movement occurs.”^{32,33} The functional definition of PNF builds on this definition to include the intention of the contractions. According to the authors, this contraction is a stabilizing contraction “in which the patient’s intention is to maintain a consistent position in space.”¹⁰

Isotonic Contractions. The traditional definition of an isotonic contraction is, “a contraction in which the external force is constant and motion occurs.”^{32,33} An isotonic contraction as defined in the PNF approach is one “in which the patient’s intention is to create movement.”¹⁰

These are subdivided into *concentric* (a dynamic shortening of the muscle), *eccentric* (a dynamic controlled lengthening), and *maintained contractions*. A maintained contraction is a dynamic contraction in which the patient’s

intention to produce movement is limited by a greater external force. This contraction differs from an isometric contraction in that the intention of an isometric contraction is to maintain a stable position.¹⁰

An example of the interaction of these various contractions occurs during the removal of a bowl from a high shelf. When reaching, the arm must concentrically raise, perform a maintained contraction to stabilize the weight of the bowl as it leaves the shelf, and eccentrically lower the bowl and arm to the counter. During this motion components of the trunk perform isometric contractions to maintain a stable position in space.

Each of these functional types of contractions needs to be specifically evaluated and facilitated. Nonvarying mechanical resistance cannot create the variables needed to stimulate these differentiated contractions. The PNF principle of manually applied appropriate resistance allows for this selective differentiation to occur. The therapist varies the type and degree of resistance to facilitate the appropriate response. The resistance must vary in application, power, and endurance to evaluate and treat the patient’s dysfunctions

of selective motor control, coordination, range of motion, strength, initiation, stabilization, and/or relaxation.

Irradiation. Resistance can also be used to produce appropriate irradiation.¹⁰ Irradiation is defined as the overflow of excitation from stronger components to weaker or inhibited components.^{15,34,35,36} This is accomplished through the application of graded resistance to stronger components to facilitate irradiation and produce an appropriate and enhanced contraction in weaker ones.

There are many variables which the therapist must consider while utilizing appropriate resistance to facilitate an efficient motor response such as: the patient's position, gravity, existing normal and abnormal reflexes, therapist's manual contacts, and body mechanics. The encouragement of controlled breathing further reinforces efficient movement.

Example. Various forms of resistance can be applied to the shoulder girdle as an effective treatment of cervical dysfunction.

- In cases of acute pain, gentle, slowly built isometrics can often decrease tone, mobilize articulations, improve circulation, and decrease pain through indirect means.
- In many individuals with cervical dysfunction, abnormalities in neuromuscular control of shoulder girdle motions are identified. This alteration of neuromuscular control is effectively treated using the various forms of isotonic contractions combined with isometric contractions. The isometric contraction allows the therapist to monitor the slowly building contraction to assure proper muscle recruitment, followed by the retraining of the isolated group with various isotonic contractions. In these cases appropriate resistance is utilized in conjunction with the appropriate technique for training control.
- In patients where more trunk or neck facilitation is desired maximal resistance is given to the shoulder girdle to facilitate appropriate irradiation.

Traction and Approximation

Traction and approximation utilize force vectors to assist the resistance and in facilitat-

ing the desired motor response.^{15,36} They supply a reflex enhancement to the volitional response to resistance. Therefore, the therapist must be aware of blending traction or approximation with resistance to ensure smooth and appropriate resistance (Fig. 11.4).

Traction. This is the elongation of a segment and separation of joint surfaces which facilitates an enhanced muscular response to promote movement or enhance stability.^{10,15} The direction of traction is always applied away from the apex of the arc of motion (Fig. 11.4).

Example. Use of general traction when treating a patient with an acute cervical spine can assist the patient in his/her ability to perform controlled contractions without pain. The PNF approach utilizes traction differently than distraction which is designed to specifically separate joint surfaces.²⁰



Figure 11.4. The force vectors of resistance and traction or approximation—combine to provide appropriate resistance and facilitation.

Approximation. A compression force towards the axis of motion resulting in an approximation of joint surfaces is Approximation. It facilitates an increased muscular response and promotes stability, and is often used when facilitating stability in weight bearing postures or positions.^{15,19,37,38} The desired response can be initiated or reinforced by a reflex—producing quick approximation, followed immediately by a maintained approximation and resistance.

Example. Use of approximation can be used to retrain postural awareness in sitting by facilitating a more stable and improved response of the trunk musculature and improve trunk stability (Fig. 11.5).

Even though reflex responses can be facilitated through use of traction and approximation, these responses are not therapeutic un-



Figure 11.5. Use of approximation—to reinforce stability and reeducation.

less coupled with a volitional contraction and appropriate resistance.

Cautions. When applying traction or approximation care must be taken to avoid increasing pain, and consideration must be given to the underlying pathology. In many cases where the joint is the source of pain, such as arthritis, judicious use of traction or approximation may decrease symptoms and allow for a more intensive rehabilitation program. Pain which is secondary to articular instability may be reduced with a combination of resistance and traction or approximation, allowing for greater facilitation of neuromuscular stabilization.

Quick Stretch

In the presence of weakness, incoordination, poor initiation, or poor endurance a volitional contraction can be heightened and reinforced through the use of spinal reflexes. PNF uses a facilitating cue termed quick stretch to offer a stretch stimulus and produce a desired stretch reflex.^{15,18}

Gelhorn defined stretch stimulus as the “increased state of responsiveness to cortical stimulation that exists when a muscle is placed in an elongated position.”³⁹ The stretch reflex is a spinal reflex that is facilitated by a quick elongation of a muscle on stretch. This stretch stimulates the extrafusal and intrafusal muscle spindles fibers to fire and produce a reflex contraction.^{18,40} This reflex response, if isolated, produces a quick, short-lived contraction. However, if resistance is applied immediately to the contraction in conjunction with an appropriate verbal command, the result is a facilitated muscular response.

The use of these neurophysiological principles, such as the stretch reflex, allows the therapist to facilitate the initiation, force, direction, or endurance of a specific motor response through quick stretch. While these principles can affect the response of individual muscles, the tool is most effective when applied to a synergistic group of muscles or a PNF pattern of facilitation. Quick stretch can be applied at the beginning of a contraction

when the muscle group is lengthened or throughout an active contraction. When utilized throughout an active contraction, the stretch reflex is facilitated from existing tension within the contracting muscle. A contraindication to the application of quick stretch is increased pain.¹⁵

Example. Consider the posterior elevation pelvic pattern which is functionally utilized in stepping backwards and scooting. To perform this pattern the latissimus dorsi, erector spinae, and quadratus lumborum must function together to achieve an efficient movement. If the patient has difficulty in initiating the contraction, just placing the muscles on stretch often will facilitate a stronger more effective pattern. If that is not sufficient, a stretch reflex can be applied to initiate the contraction and repeated either at the beginning or through the range.

Verbal Stimuli

The therapist's verbal command is a primary link between reflex responses and the patient's volitional response.¹⁵ Without the use of verbal commands, there is no cognitive reeducation taking place, only reflex responses to proprioceptive input. This is a primary functional consideration with all patients because a reflex response must become volitional to facilitate the patient's independence in motion activities.

Verbal commands, coupled with manual contacts, provide the therapist with the primary tools for establishing communication and cooperation. Verbal commands should be simple, concise, and unidirectional. In addition, the quality of the verbal command should vary depending upon the type of motor response desired from the patient.¹⁵

Example. In a sports rehabilitation setting, when a patient is stable with minimally irritable symptoms, the goal of treatment is a heightened motor response and strength. The therapist's energetic and enthusiastic verbal commands can facilitate the patient's excitement and participation in the treatment. However, with a patient who has acute, highly irritable cervical dysfunction, the commands are most effective when given in a quiet and assuring manner. This is to promote relaxation and to not trigger

heightened or easily aroused neuromuscular responses.

Summary. Verbal commands are used to:

- coordinate volitional effort with reflex response,
- define the type of muscular contraction,
- define the direction of motion,
- signal timing of relaxation of contraction,
- facilitate increased involvement and arousal,
- stimulate generalized relaxation.

Visual Stimuli

The visual system is important in normal development and coordinated use of the body (Fig. 11.6). The therapeutic utilization of visual stimuli goes beyond the use of vision to teach an activity. Developmentally, the neuromuscular system gains its control in a ce-



Figure 11.6. Visual stimuli—reinforces the other principles of facilitation and enhances the patient's response.

phalic-caudal direction. Movement of the trunk and extremities can be facilitated by the incorporation of the visual system, which requires integration of the head and neck. Failure to evaluate and include the visual system in a rehabilitation program can inhibit or retard the development of complete and coordinated trunk and extremity control. In addition, balance and equilibrium responses rely heavily on visual input for accurate interpretation of spatial relationships.^{15,30,41,42}

Patterns of Facilitation

The patterns of facilitation were discovered by Kabat in the final stages of his development of PNF.^{15,27} Through the utilization of all the previously identified principles, he began to understand and recognize the inherent movement patterns which humans utilize to perform normal functional and athletic activities. He observed that normal coordinated activities are accomplished by the moving of the extremities and trunk in diagonal and spiral motions in relationship to each other. He observed that muscular responses were strong and coordinated when resisted within specific diagonal patterns. In addition, the use of reflex facilitation, such as the stretch reflex, was most effective when the part was elongated in its specific diagonal. This observation made Kabat question the validity of using cardinal plane motions in the rehabilitation of functional activities, because normal motion is performed in diagonal and spiral patterns. Through trial and error, Kabat and Knott developed the specific trunk and extremity patterns.

Patterns of facilitation provide the therapist with tools to evaluate and treat dysfunctions of neuromuscular control and mobility of selective spinal articulations, as well as the ability to integrate synergistic muscle groups within the patterns. As control is developed, synergistic muscle activity is integrated into functional whole body movements. Through use of patterns of facilitation, the patient is provided the opportunity to correctly perform and learn the desired motor response and in-

tegrate that response into daily functional activities.

The patterns exist in narrow diagonals in relationship to the central axis of motion of the extremity and trunk. Each pattern is as wide as the part being treated and moves within a smooth arc of motion. Three components of motion are blended within each diagonal movement pattern.

In the Trunk. The components are: flexion/extension, lateral movement, and rotation (Figs. 11.7A,B,C).

In the Extremities. The components are: flexion/extension, abduction/adduction, and rotation (Figs. 11.8A,B).

Parameters. Each pattern can be identified by the following parameters.^{10,23,24}

1. When in the elongated position all synergistic muscles are equally on stretch. In this manner the patient's functional range can be evaluated.
2. The stretch reflex is optimally facilitated within a synergistic group of muscles at one time.
3. Clinically, it can be shown that a muscle contraction is stronger when performed within a facilitation pattern than outside of the pattern. It is theorized that muscles work together more efficiently when placed within these patterns and the contraction is more readily enhanced by irradiation. An example is the function of thumb and little finger opposition, which is easily demonstrated to be not only stronger, but more easily recruited when the upper extremity is placed within the extension-abduction pattern.
4. Resistance to an extremity pattern will facilitate a contraction within the related trunk patterns.
5. Increased tone and clonus are generally reduced when the part is specifically placed within a component of the diagonal. This is often dramatically illustrated in a patient with increased abnormal tone of the upper extremity or an immediate reduction in tone when the scapula of that same extremity is placed into posterior depression.¹⁰

By using the PNF patterns of facilitation, the therapist can more quickly and effectively

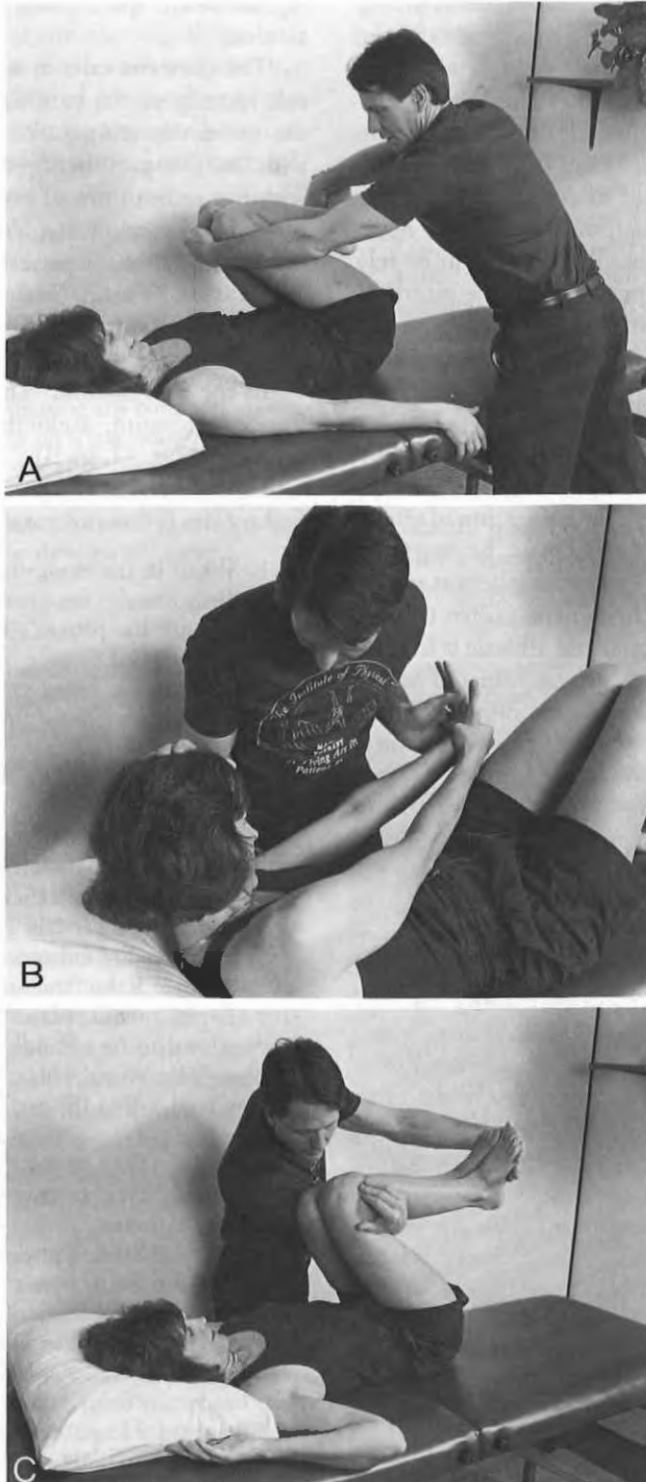


Figure 11.7. Available trunk patterns include: **A)** lower trunk flexion; **B)** upper trunk flexion with chopping; **C)** lower trunk lateral flexion with rotation.

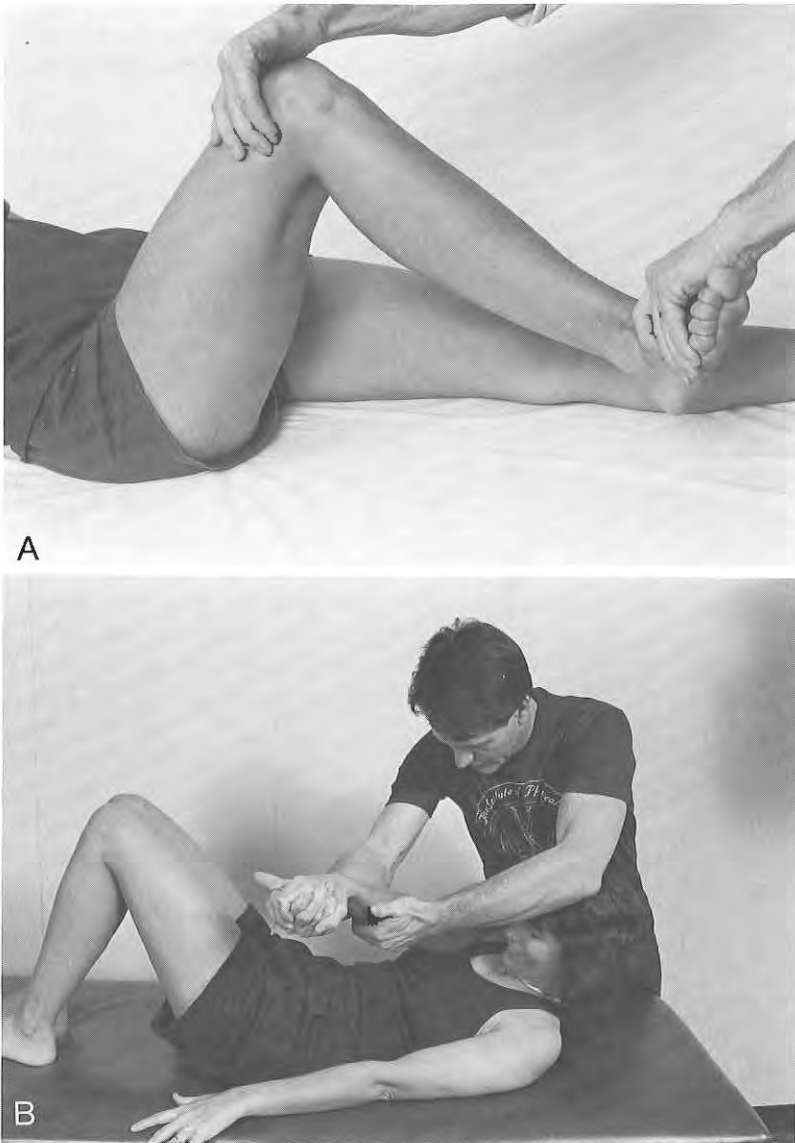


Figure 11.8. Extremity patterns include: **A)** lower extremity flexion/adduction/internal rotation, **B)** upper extremity flexion/adduction/internal rotation.

evaluate neuromuscular control and range of motion within synergistic muscle groups. When dysfunctions are identified, specific PNF techniques are applied to enhance the desired movement.

Example. The lower trunk extensor pattern can be utilized to selectively evaluate for hypo- and hypermobilities of the spine, and then treat the identified dysfunction through specific

treatment procedures described later in the chapter.

Timing

Normal timing refers to the *efficient sequencing* of dynamic muscle contractions to achieve a desired functional result.^{10,15,43} This includes the sequence in which the muscle fires and the controlled interaction between mobility

and stability of the selected components of a movement. In the orthopedic and sports injured population there is often a deficit in normal timing of motions during the performance of a pattern within symptomatic regions. These deficits are identified through manual and observational assessment.

Example. Orthopedic patients frequently demonstrate an inability to brace, or to stabilize the lumbar spine during normal or stressful activities.^{21,44} The contraction of the trunk muscles should occur reflexively in response to any external demand which could potentially stress the spinal structures. Often the trunk muscles will test strong with conventional muscle testing, but when tested within a mass movement pattern or during a functional activity (such as push/pull activities) the contraction will be delayed or nonexistent. Through appropriate use of reeducation techniques abnormal timing can be improved and integrated into normal functional activities. (See Fig. 11.9)

Appropriate Techniques. Treatment of dysfunctions of normal timing can occur through multiple avenues.

- Reduce the motion or activity to the simplest components and facilitate an optimal

contraction of each individual component. Then combine these individual components together into the desired functional motion or activity.

- Appropriate use of resistance, quick stretch, and verbal command are used to reinforce normal timing.
- If abnormal timing is evaluated in a complex skill such as walking, less complex motions such as rolling and crawling can be used initially to train timing and kinesthetic awareness.

Example. One of the most valuable activities to observe for the assessment of a patient's inherent patterns of motions is rolling. To roll efficiently all components of the neuromuscular skeletal system must function in integrated and coordinated patterns. Each person should have the capacity to perform rolling from supine to sidelying in flexion, and roll from prone to supine with extension (Fig. 11.10). The initiation and performance should be executed with minimal effort. If the patient rolls with any other pattern, attempt to see if the efficient pattern is an option by providing verbal clues. All identified dysfunctions are selectively treated by beginning with the most basic motion and progressing to the



Figure 11.9. Utilization of resistance to the lower extremity flexion/adduction pattern to facilitate irradiation to the abdominals for functional bracing.

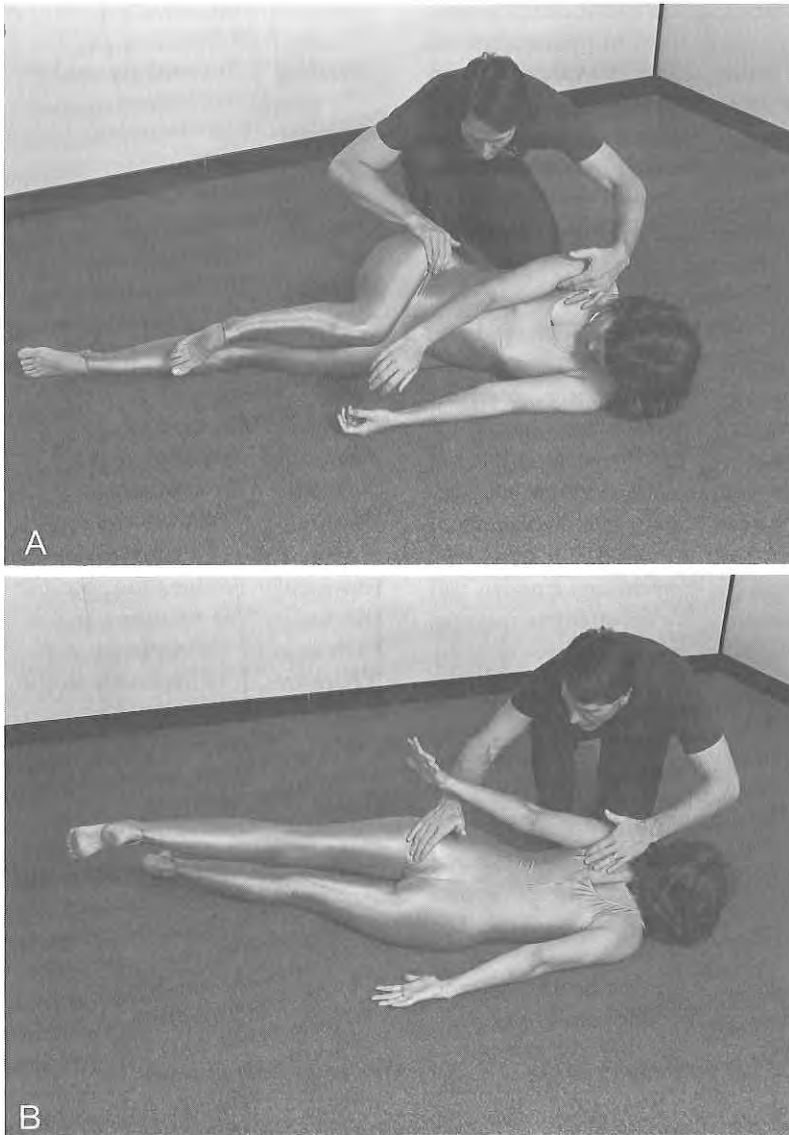


Figure 11.10. Rolling is facilitated through the principles of PNF to reeducate both flexion and extension.

complete roll. This motion should be a part of the patient's home program, through the use of tubing, pulleys, or sports cords.

FUNCTIONAL EVALUATION

The integration of PNF treatment techniques into a comprehensive rehabilitation program is dependent upon a thorough and continuous evaluation system. Initially this should include

an in-depth subjective and objective evaluation.^{2,3,5,20}

Initial Evaluation

The subjective evaluation provides insight into the patient's symptoms, and his/her history, irritability, and normal course. Clear and concise subjective data can assist both the pa-

tient and therapist in gauging the effectiveness of treatment.

The orthopedic objective evaluation and standard neurological testing provide objective parameters by which the therapist and patient can assess progress. These parameters include specific measurements and documentation of the patient's posture, range of motion, symptom-producing motions, joint and soft tissue mobility functional capacities, and neurological involvement.

The neuromuscular assessment^{10,13,15} generally begins with observing activities which can reveal the functional capacity of the symptomatic region. One assesses the interaction of the symptomatic region with related segments of the kinematic chain for activities performed both efficiently and inefficiently. Are the movements smooth and coordinated, and is there an effective interaction between stability and mobility?

Characteristics of Neuromuscular Control

In conjunction with the results of the subjective and objective evaluations, specific movement patterns are selected for manual neuromuscular assessment. Utilizing the principles of PNF, this manual assessment reveals the functional status of the neuromuscular system or characteristics of neuromuscular control. The patient is evaluated in various postures and movements to identify and assess the following characteristics of neuromuscular control and their effect on pain and symptoms:^{10,23,24}

- Ability to relax and allow the part to be moved passively.
- Quality of initiation of movement.
- Coordination and control of contraction.
- Speed of contraction.
- Power of contraction.
- Ability to adjust power to meet functional demands.
- Ability to actively and with resistance to achieve a desired ROM.
- Ability to effectively produce an isometric contraction.
- Ability to perform a combination of isotonic

(concentric, eccentric, and maintained contraction).

- Ability to coordinate and smoothly reverse direction of motion.
- Neuromuscular balance between antagonists and agonists.
- Ability to coordinate contraction with synergistic muscle groups.
- Ability to produce appropriate irradiation to synergistic parts of the body

The PNF approach is organized upon the foundation of identifying dysfunctions of neuromuscular control through feeling the motion, palpation, and observation. Each of the above characteristics is an essential component for optimal function of the system as a whole. A dysfunction of one characteristic may indicate not only the necessity for neuromuscular reeducation, but can also require the utilization of other manual techniques, such as joint and soft tissue mobilization.^{23,24} Therefore, it is necessary to fully understand how to manually assess each characteristic in order to integrate the findings into a total subjective and objective evaluation.

IDENTIFYING DYSFUNCTIONS

Passive Mobility

Passive movement of a segment through the arc of a PNF diagonal assists in the identification of the accessible passive range of motion, the patient's ability to relax, and the presence of neuromuscular holding patterns.^{10,15} *Neuromuscular holding patterns* are unconscious states of unnecessary increased tone, which restrict passive and active mobility. To assist in selecting the appropriate treatment techniques, a differentiation needs to be made between neuromuscular dysfunctions and those stemming from soft tissue or articular restrictions.

Example. In patients with a forward head posture and/or anteriorly displaced shoulders, passive limitations will often be identified into the scapula pattern of posterior depression. This limitation can be a result of increased tone in the pectoral, cervical, or upper thoracic muscle groups. On the contrary, the pa-

tient may demonstrate the ability to totally relax the segment being moved, but still have motion interference which clearly indicates possible soft-tissue or joint involvement.

Active Mobility

The source of an identified limitation can be further clarified by active performing of the PNF diagonal previously assessed passively. If there is more range actively than passively it is an indication that the patient has difficulty relaxing. When less active than passive range exists, this is an indication of neuromuscular dysfunction. Observing a pattern performed actively provides information about the initiation, quality, control, range, and directional capabilities.^{10,41}

Initiation

To evaluate the quality of initiation, the part is taken to the elongated portion of a pattern. The therapist couples verbal commands with resistance to determine the patient's ability to initiate the motion. The response is evaluated for sluggishness, delayed response, hyperactive responsive, or inappropriate recruitment.

The inappropriate recruitment would allow for movement, but not in the appropriate direction.

Example. Patients with lumbar pain often demonstrate a poor responsiveness of the abdominal musculature. This is often revealed through sluggish initiation of the pelvic anterior elevation pattern (Fig. 11.11). This assessment supplies critical information about the patient's ability to effectively recruit the trunk muscles at the demand of environmental stresses. Once this dysfunction is identified, a specific treatment program is designed to improve neuromuscular responsiveness.^{6,12,22,44}

Coordination and Control

Through the use of resistance, coordination and control can be evaluated. From initiation, the contraction should be smooth and coordinated throughout the available range of motion. If the pattern of movement is dysfunctional, the patient often demonstrates muscle substitution to accomplish the movement. This is evident if the pattern is jerky, incoordinated, and deviates from the appropriate direction of movement.



Figure 11.11. Evaluation of the anterior elevation pelvic pattern reveals the quality of responsiveness

of the abdominal muscles and coordination with lateral flexors and extensors.

Example. In patients with fixed kyphotic thoracic curves, there exist anterior to posterior structural and muscular imbalances, which can diminish neuromuscular control and directional capabilities. In this example, the scapular stabilizers are often overstretched, while the pectoralis major and minor are shortened or over-developed. As a result, resistance to posterior depression of the scapula (which requires contraction of the scapula stabilizers) often results in pure depression, retraction, or anterior depression. The posterior depression motion may be altered by the dominance of the anterior musculature, the fixed structural thoracic position, and the loss of efficient recruitment and contraction of the posterior depressors and stabilizers.^{6,10} This imbalance and necessary compensation places added strain on the lumbar and cervical spine.

The demand of manual resistance produces a functional response which clarifies the patient's ability to efficiently recruit the scapular stabilizers, inhibit the pectoral musculature, and move the shoulder girdle on the underlying rib cage. Treatment should emphasize initial lengthening of the anterior and superior structures and reeducation of the scapular depressors.

Strength and Speed

Through the application of resistance the therapist can assess the patient's strength and speed capacity. Traditional strength testing through manual muscle testing procedures may not be a complete or accurate predictor of functional capabilities. Efficient function is not solely dependent upon an individual muscle's strength, but also the appropriate motor response of synergistic muscle groups.^{6,15,32,45} Therefore, functional strength testing must incorporate an analysis of each muscle group's ability to respond to the functional requirements as a primary mover, secondary mover, antagonist, neutralizer, stabilizer, and its synergistic capacities.

Patients often demonstrate a diminished ability to vary the speed of a contraction in

response to the demands of activity. This characteristic is assessed by applying resistance and varying the verbal control to determine the patient's ability to recruit and execute a specific speed of motor response.

The patterns and techniques of PNF provide a comprehensive system for the assessment and retraining of strength and speed. The PNF diagonals requires functional combinations of muscles' actions, which allows each one to function in various capacities (i.e., primary mover, stabilizer, etc). A quick assessment of all the diagonals in the region being tested gives a more accurate functional strength analysis than individual muscle testing.

By varying the resistance, the therapist also determines the patient's ability to adjust the strength and speed of the contraction to meet the diversified functional demands placed on the segment during daily activities. This will identify segmental weaknesses which can cause altered arthrokinematics, postural deviation, and increased soft tissue strain.

Combination of Isotonics

In addition to the evaluation of general strength, there needs to be an assessment of performance and transition between the three type of isotonic contractions (concentric, eccentric, and maintained). Each isotonic contraction must be specifically evaluated and retrained, since the control and strength developed while performing one type does not necessarily directly translate to the others. We have termed this evaluation and treatment tool: combination of isotonics.¹⁰

Concentric Contractions. To evaluate and treat the ability to perform concentric contractions, the patient is given the command, "Push" or "Pull," while the therapist applies appropriate and variable resistance throughout the desired or available range.

Eccentric Contractions. These are evaluated and treated by giving the command, "Slowly let go" while the therapist applies appropriate lengthening resistance.

Maintained Contraction. To perform

them the patient is given the command, "Keep it there, don't let me move you," while the therapist quickly applies matching resistance to prevent motion. If a dynamic contraction is not facilitated, the therapist may use the command "Push" or "Pull" while applying a stronger resistance that allows only minimal motion.

Isometric Contraction

The patient's ability to produce an isometric contraction is evaluated in addition to the combinations of isotomics. For assessing and retraining the ability to perform this contraction, the patient is given the command, "Hold, don't let me move you, don't push into me." The therapist *gradually* applies and releases the resistance, attempting to *match* forces with the patient. The verbal command is important to reinforce to the patient that he is not to push or pull, only maintain his position. In cases where the patient is unable to perform an isometric contraction, low level maintained isotomic contractions may have to be initially utilized. The goal is to progressively facilitate the patient's capacity to perform true stabilizing contractions on demand, or to facilitate a selective motor recruitment where substitution is prevalent.

Reversals

The ability to reverse direction is a primary control feature of the neuromuscular system.^{32,47-49} Inadequate control, speed, or strength of a reciprocal motion can result in altered arthrokinematics^{6,23,24} and the development of compensatory movement patterns.

Example. By resisting flexion/adduction/external rotation of the lower extremity, followed by extension/abduction/internal rotation of the lower extremity, the therapist evaluates the patient's ability to perform reciprocal motions. The change in directions is critiqued for smoothness, direction, proper speed, and synergistic control of the prime movers versus the stabilizers. At the same time, while the extremity is performing the

reciprocal motion, the trunk is assessed for its capabilities to stabilize.

Agonist/Antagonistic Balance

Secondary to structural dysfunctions, herniated nucleus pulposus, or overuse syndromes, a functional imbalance may occur between the use of the antagonistic muscle groups. This manifests itself as many of the dysfunctions previously discussed, such as poor coordination, inefficiency at reversals,^{6,12,44} or neuromuscular holding patterns such as backward bending of the lumbar spine.

Trunk Control

Trunk control depends upon the integration of stability and mobility. It is essential for efficient function and the health of associated structures.^{41,50} Dysfunctions of trunk motor control lead to aberrant movement patterns, and places abnormal stress on the soft tissues and articular structures. This stress, if repetitive or excessive, often precipitates symptoms and degeneration. Motor dysfunctions are often overlooked in the normal course of evaluation and treatment, as emphasis is placed on the structural components. Therefore, a basic tenet of PNF is to evaluate trunk motor control with any musculoskeletal problem in an extremity or the trunk.

For efficient trunk or extremity function to occur these interconnecting segments of pelvis and scapula must have the capacity to function independently and in coordinated manner with the extremity and trunk. In an efficient state the trunk provides appropriate proximal stability or controlled mobility to support optimal task or postural performance.

A functional trunk assessment is conducted by first evaluating the pelvic and shoulder girdles for appropriate characteristics of neuromuscular control and the pelvis and shoulder integration with the axial skeleton.

SYMPTOMS AND SELECTION OF TREATMENT TECHNIQUES

During the performance of passive, active, or resisted PNF diagonals, the therapist is always

alert to the reproduction of the symptoms. The combinations of functional demands placed upon articular and soft tissue structures during any given pattern may identify restrictions or reproduce symptoms in a dynamic way that isolated structural assessment may not.

Assessment

A skilled practitioner can accomplish a full neuromuscular assessment in a few minutes and integrate the treatment of identified dysfunctions within the treatment program.

Example. In cases of recurrent inversion sprains of the ankle, the lower extremity patterns are assessed. Each aspect of the lower kinetic chain, including trunk, is evaluated for the multiple components of efficient neuromuscular control. A frequently identified dysfunctional component is poor control of dorsiflexion with eversion and hip internal rotation in the flexion-abduction pattern. When identified, a specific facilitory technique is chosen and applied during the performance of the pattern, a more responsive contraction of dorsiflexion with eversion. As the technique is being applied, the status of the dysfunction continues to be evaluated.

If an improvement is noted during the treatment process the facilitation techniques used are gradually eliminated until the pattern can be performed with minimal facilitation. The improved pattern is integrated into more complex patterns of movement and functional activities, specifically those movements and activities that have been previously assessed as symptomatic or dysfunctional. As coordination, muscle recruitment, strength, and control improves normal activities become less stressful upon the symptomatic structures and the potential of reinjury is reduced.

THE TECHNIQUES OF PNF

Because proprioceptive neuromuscular facilitation is defined as the utilization of the proprioceptors to hasten or make easier the learning of a neuromuscular task,²⁷ application of ideal technique is essential. The success achieved through PNF is derived from the

therapist's ability to appropriately identify faulty characteristics of neuromuscular control and analyze and select the appropriate PNF technique. These techniques focus upon the functional attribute of the patient's motor response, utilizing facilitory tools such as resistance, stretch reflex, approximation, and traction.

Once a technique is selected and applied, the therapist evaluates the results and proceeds by choosing from the list of options (Table 11.1).

The following techniques were developed in response to clinically identified dysfunctions. Each technique evolved through a trial and error application of the principles of PNF and subsequent observation of variations in the patient's functional needs.

Rhythmic Initiation (RI)¹⁵

Purpose. RI is used to evaluate and treat the patient's ability:

Table 11.1
Options during PNF Procedures

-
1. If there is no improvement in the motor response—
 - a. Evaluate whether the technique was effectively applied, and if not, correct the technique and apply again, or
 - b. Select and apply another technique, or
 - c. Utilize irradiation from a stronger synergistic component, or
 - d. Address an associated dysfunction in conjunction with applied technique.
 2. If a partial resolution has occurred in the motor response—
 - a. Continue to utilize the technique to gain further improvement, or
 - b. Integrate improvement into functional activity, or
 - c. Teach patient self exercise program to maintain and enhance gains between treatments, or
 - d. Wait until next treatment to address dysfunction again.
 - e. Address an associated dysfunction in conjunction with applied technique.
 3. If dysfunction is resolving or has resolved—
 - a. Judiciously reduce use of facilitory technique and train patient to move efficiently against resistance without facilitation, or
 - b. Integrate improvement into mass movement patterns and functional activities.
-

- to allow passive motion,
- to actively contract in a smooth, rhythmical fashion
- to perform movement at a consistent rhythm against resistance.

Indications. RI is utilized for the treatment of dysfunctions which affect the initiation, speed, direction, or quality of the contraction.

Application. In preparation to apply the technique, the patient is positioned in a posture conducive to relaxation. The technique is divided into three distinct components; passive, active, and resisted.

Passive. The technique is initiated by requesting the patient to relax and allow the therapist to perform the desired motion passively. An appropriate rhythm of movement is established as the patient relaxes. Manual contacts can be nonspecific.

Active. When a smooth and rhythmical passive motion is achieved, the therapist asks the patient to minimally assist with the motion. With each successful repetition, the patient increases the force of contraction. If the patient's participation interrupts the smooth rhythmical motion, the therapist resumes passive motion and tries again to have the patient participate at a lesser degree. Manual contact must be specific to direction of movement.

Resistive. Appropriate resistance is applied as the patient increases active participation. The goal is to slowly increase resistance with each repetition while maintaining the same rhythm and excursion of motion. Resistance is pivotal to the reinforcement of volitional control.

Example. The rhythmic initiation technique can be helpful to progressively facilitate active and resistive contractions in patients with acute pain. For acute lumbar symptoms, passive pelvic motion in pain-free range can provide oscillatory inhibition. As the patients relax and allow the motion, they are requested to provide a minimal active contraction. This active contraction can begin to inhibit pain and spasm, and provide a muscular pumping action for the region. If the active contraction is built to a point where resistance can be added, it is added minimally at first and, if possible, with traction.

Often reversals of these small motions are helpful.

Combination of Isotonics (COI)¹⁰

Purpose. COI is used to evaluate and develop the ability to perform controlled purposeful movements. This is accomplished through assessment of the patient's capacity to alternate between the three types of isotonic contractions (concentric, eccentric, and maintained).

Indications. COI is indicated for the treatment of deficiencies in strength, the ability to appropriately perform these three isotonic contractions, ROM, and decreased neuromuscular coordination and awareness.

Application. This technique is coupled with the evaluation process. The therapist begins by assessing the patient's capacity to perform and transition between the three types of isotonic contractions within the normal range of a selected agonistic contraction. The exact timing and speed of the transitions will depend upon the individual patient and the goals of treatment. When a dysfunction is identified the technique is initiated by utilizing the type of contraction the patient performs best.

Identified Dysfunction. Included are—

Poor Concentric Control: Problems with initiation, power of concentric contraction, coordination, and direction of motion are treated through use of maintained and eccentric contractions.

Example. If the patient is unable to easily move a body part to a specific target position, the body part is placed at that point. A maintained contraction is built followed by a short-range eccentric contraction with an immediate concentric contraction to return to the target position. This procedure is repeated until the concentric contraction can be performed to the target point.

Poor Eccentric Control: Difficulty in controlled eccentric contractions with appropriate strength is treated through utilization of maintained and concentric contractions.

Example. A ratchety quality of an eccentric contraction performed against appropriate resis-

tance. Once the ratchety type of contraction begins, a maintained contraction is initiated, then a short-range concentric followed by an eccentric. This procedure is repeated until optimal control is gained, which is determined by reassessing motion quality.

Inefficient Maintained Isotonic: The inability to perform a maintained contraction, with optimal strength and endurance is treated through utilization of concentric and eccentric contraction.

Example. The inability to hold a position would be treated by slowly switching between short-range concentric and eccentric contractions until a maintained one can be established.

Inefficient Neuromuscular Control: The goal is to be able to functionally combine these three contractions in a smooth and coordinated manner.

Example. Combination of isotomics can be utilized to train ADL activities such as training push/pull activities. Initial training begins with resisted gait to facilitate the proper pelvic and lower extremity mechanics. Once developed, resistance is applied to the upper extremities through direct or indirect (use of a dowel) to train through combination of isotomics appropriate weight shift, weight acceptance, balance, force production, and shoulder girdle stability. (See Figs. 11.12, a, b, c).

Decreased Range of Motion: COI is used to treat decreased ROM and offers an alternative to traditional hold or contract relax. The repetition of the internal shortening and lengthening of the muscle fibers against resistance yields a lasting increase in ROM of the soft tissues and subsequently affects associated joint motion. This is effectively demonstrated by applying COI to the scapula patterns when decreased cervical-thoracic translation is observed during active cervical rotation.

Repeated Quick Stretch (RQS)^{15,16}

Purpose. RQS is the repeated use of the stretch reflex to assist with initiation of a muscular response or to enhance strength and endurance of a preexisting contraction. This

is based upon the principle that repeated excitation of a pathway in the central nervous system promotes ease of transmission of impulses through that pathway.¹⁶

Indications. RQS is a valuable tool for enhancing initiation and force of a weak contraction, for reducing fatigue, improving endurance, and increasing the patient's awareness of the motion.

Application. There are two basic forms of RQS. It can be performed from elongation or it can be superimposed upon an existing contraction.

Repeated Quick Stretch from Elongation (RQS-E)¹⁰

Purpose. RQS-E is utilized to treat the following dysfunctions: sluggish or delayed initiation, inability to pull through complete range, fatigue, and poor coordination of the motion.

Application. RQS-E is applied by placing each of the muscle components in their lengthened range. In most cases this will be the beginning position of a PNF pattern of facilitation. A contraction is initiated by a stretch stimulus and coordinated with a timed verbal command. The reflex contraction is reinforced through the immediate application of appropriate resistance. The contraction is resisted through the active range of motion or to fatigue. The part is then passively or actively returned to the elongated position and process repeated. Because the stretch reflex is facilitory, the motion can be repeated multiple times to enhance the learning, strengthening, and conditioning process, with minimal fatigue.

Repeated Quick Stretch Superimposed upon an Existing Contraction (RQS-SEC)¹⁰

Purpose. RQS-SEC is utilized to treat the following dysfunctions: a weakening contraction, fatigue, poor control in a specific portion of the range, inability to actively complete the desired range, diminished control of selected

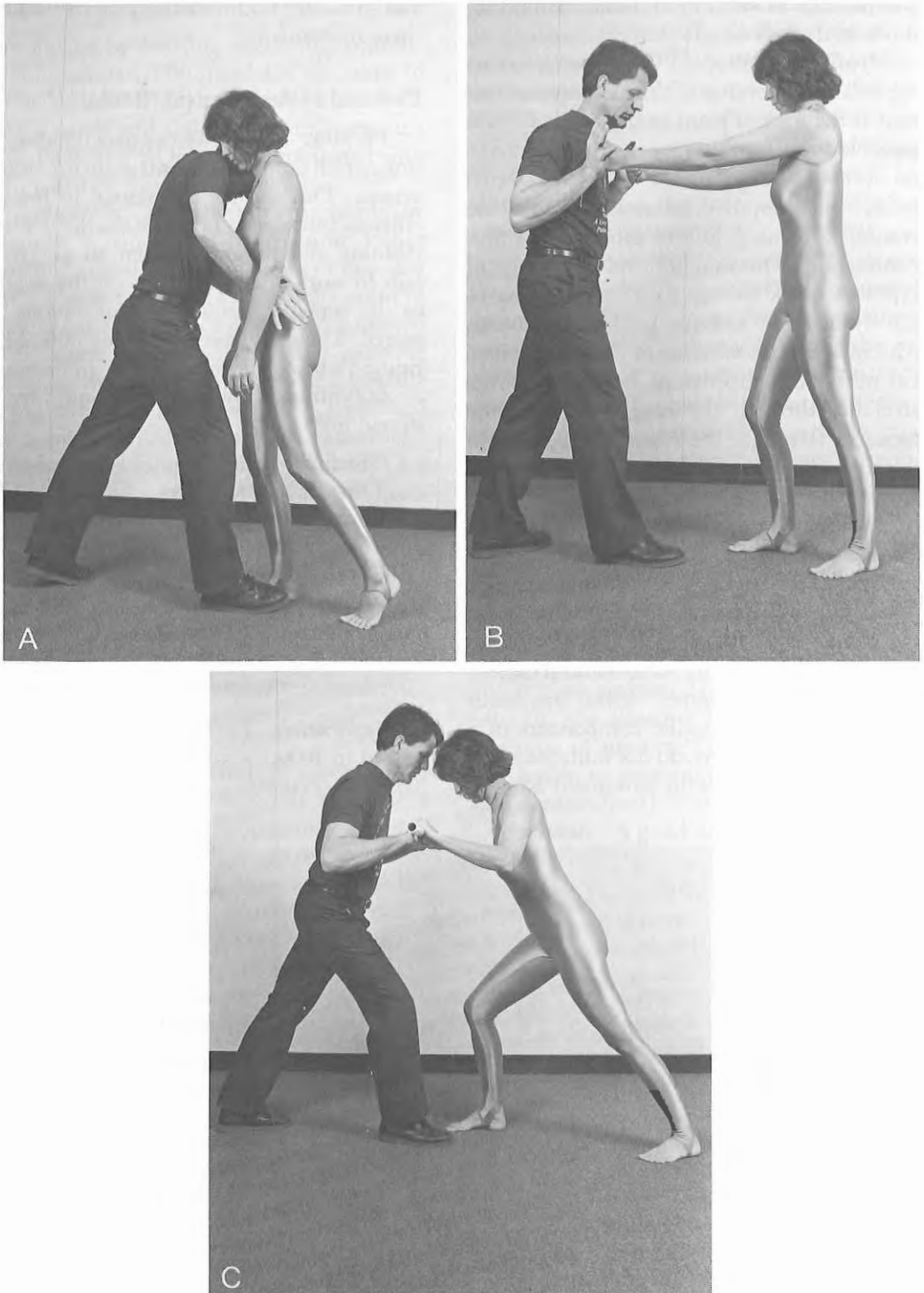


Figure 11.12. Push-pull activities broken down into: **A)** resisted gait; **B)** direct resistance through the extremities; **C)** indirect resistance through a dowel.

components of the motion, and inability to move in desired direction.

Application. RQS-SEC is a quick stretch applied to the tension of the existing contraction at the desired point in the range. This is possible because resistance maintains tension on the contracting muscles, to which a stretch reflex is superimposed, followed by immediate resistance applied to the subsequent reflex contraction. The number and frequency of repeated quick stretches varies according to the dysfunction and the goal of treatment. Multiple repetitions of the motion can be performed while applying repeated quick stretches through the range. As with any facilitory technique the therapist should begin to reduce the use of RQS to train the patient to function efficiently without the facilitation.

Example. Resisted crawling is an important developmental activity which influences and retains the trunk's ability to maintain stability while the extremities support and move the trunk. The goal of treatment is to train the patient to maintain a stable neutral lumbar spine, while the therapist resists the lower extremities. Often specific components of a lower extremity pattern do not initiate and/or fire during the range of the movement. RQS-E

and -SEC are both valuable tools to facilitate these movements.

Reversal of Antagonists (ROA)^{10,15}

Purpose. Most activities depend upon coordinated control of antagonistic muscle groups. This control is essential to produce efficient interaction between the demands for mobility and stability. When an antagonist fails to work in accordance with the demand of the activity, function is immediately impaired. The techniques are based upon Sherrington's principle of successive induction.⁴⁹

Indications. The ROA techniques are designed to:

- Facilitate coordinated transitions between reciprocal contractions,
- Facilitate a weaker antagonist,
- Reduce fatigue,
- Improve coordination,
- Increase active ROM,
- Enhance carry-over of reciprocal function into functional activities (Fig. 11.13), and
- Produce a reduction in antagonistic activity.

Application. There are two techniques involved in ROA: isotonic reversals and stabilizing reversals.¹⁰



Figure 11.13. Resisted crawling—used to facilitate functional trunk stability.

Isotonic Reversal (IR)

IR is applied by resisting alternating concentric contractions. The speed and the range of motion utilized is dependent upon the individual's needs and abilities. Techniques such as RI, COI, and RQS can be combined with IR to enhance the motor response.

Application. The technique is begun by initiating a concentric contraction, either through a verbal command alone or one that is timed with a stretch reflex. At the point in the range, if a reversal of directions is desired the therapist smoothly shifts from applying resistance with both hands to one (usually freeing the proximal hand). The free hand then applies manual contact to the antagonistic surface, and for a brief time the hands are contacting both surfaces. A reversal of direction is elicited through a verbal command and if necessary a quick stretch. The goal is to train the patient to shift smoothly and effectively from one pattern to the other.

A weaker agonist group can be facilitated by applying manual resistance to the antagonist pattern before the reversal or by combining the repeated quick stretch techniques within the IR.

When there is difficulty in reversing direction smoothly, the therapist may use a maintained isotonic to the agonistic motion. This maintained isotonic contraction will facilitate the antagonists motion and allow the therapist time to change manual contacts.

If the patient fatigues easily in one direction while applying RQS-F, an IR can be combined to reduce fatigue.

As the patient learns to reverse directions smoothly with simple nonweight-bearing patterns the skills are advanced to more complex functional activities.

Stabilizing Reversal (SR)¹⁰

SR, also called *Rhythmic Stabilization*,¹⁵ is applied by resisting alternating isometric contractions. The goals of the technique are to improve stability around a segment, to increase positional neuromuscular awareness, to improve posture and balance, and to enhance strength or stretch sensitivity of extensors in

the shortened range. The technique can also be applied to reduce pain, facilitate relaxation, and increase ROM. This technique also offers the therapist a significant amount of information about the patient's ability to reinforce the contractions through appropriate irradiation.

Application. Manual contacts can be placed either on one side of the trunk or extremity, or on both sides. The therapist begins by gradually increasing resistance through both hands coupled with a verbal command, "Keep it there; don't let me move you." The therapist slowly increases the resistance in direct proportion to the patient's response. This matching or isometric contraction is built to a maximal level without promoting a concentric response. Once the contraction has plateaued, the therapist can slowly change the manual contacts to place a varying demand on the stabilizing muscles. To shift a manual contact, one hand must adjust resistance to maintain the contraction while the other hand slowly releases its resistance. The free hand is then shifted to another appropriate surface. The transition must be smooth, not allowing for any relaxation or initiation of attempted motion. If the patient is not able to perform an isometric contraction a maintained isotonic contraction is used.

Example. A good illustration is the application of resistance to the shoulder girdle region to promote trunk stability in sitting. As the patient is instructed to maintain a balanced position, the therapist slowly begins to apply resistance to the trunk through manual contacts at the shoulder region. If the resistance is applied too quickly, the patient may respond with an active isotonic contraction of the shoulder girdle muscles. By applying the resistance slowly, the therapist not only encourages an isometric contraction of the shoulder girdle region, but facilitates irradiation to the trunk muscles in an isometric mode. As the therapist increases the resistance, the patient's response builds to the level at which the trunk is holding a maximum isometric contraction. At this time, the therapist slowly changes the manual contacts in a smooth and coordinated manner, so as to

maintain the isometric nature of the trunk contraction (Fig. 11.14).

Contract Relax (CR)¹⁵

Purpose. Contract relax utilizes the development of muscle tension through an concentric or maintained contraction to facilitate relaxation and stretching of the intrinsic connective tissue elements of that muscle.

Indication. To increase range of motion of the myofascial unit, by facilitating relaxation and improving extensibility of the myofascial tissues. Relaxation of unnecessary muscle tension may also serve to improve local circulation.

Application. To perform a *CR technique*, the therapist first places the segment at the point of limitation within the movement pattern. Resistance is given to a concentric contraction of either the restricted agonist (direct

contraction), or to the antagonist (reciprocal relaxation). All components of the pattern should be resisted and a few degrees of motion allowed to occur. Special emphasis should be placed on the rotatory component of the pattern, as it will facilitate a more complete contraction and relaxation. The duration and intensity of the contraction should be sufficient to generate a strong contraction within the target muscles. Following the contraction, the patient is asked to completely relax, and upon full relaxation the segment is passively or actively taken into the new available range. Resisted motion into the new range can be used for reinforcement, strengthening, or further reciprocal inhibition.^{5,15,18,52-55}

Hold Relax (HR)¹⁰

Purpose. Like contract relax, HR is used to facilitate relaxation and increased range,



Figure 11.14. The technique of Isometric Reversals (IR)—applied to the shoulder girdle region in sitting to facilitate a better stabilizing response and postural awareness.

utilizing an isometric rather than an isotonic contraction.

Indication. In the presence of pain or when the concentric contraction is overpowering, an isometric contraction provides greater control of the procedure.

Application. The part is placed in a pain-free portion of the range and the isometric contraction is slowly built. The verbal command, "Hold, don't let me move you" is given. In cases with highly irritable symptoms the facilitated contraction may be minimal. In some cases, the technique is most effectively applied to a pain-free portion of the body to create indirect relaxation through irradiation. The segment may then be moved actively or passively to the new range, or the technique may be repeated without motion to gain further relaxation or pain reduction.^{10,15}

SPECIFIC DYSFUNCTIONS

Pain

Determining the level of irritability is the first consideration in the treatment of pain.² If the symptoms are highly irritable the goal of treatment is the reduction of symptoms, with extra caution taken not to exacerbate those symptoms.

The first aspect of treatment is to identify positions which reduce symptoms and provide appropriate supports. In addition, an important adjunct to treatment is the use of ice, which is most effective if utilized while treatment techniques are being applied. The authors personally prefer the icing system developed by Kabat and Knott, which uses towels soaked in a bucket of shaved ice and water. These towels are wrung out and placed over the painful and surrounding regions, and changed every few minutes.^{15,56}

The techniques of choice for *irritable symptoms* are stabilizing reversals and hold relax. These techniques are applied to components which facilitate appropriate irradiation. As relaxation occurs and if symptoms reduce, controlled use of combinations of isotonic can begin to assist in improving mobility, circulation, and relaxation of the symptomatic region. Also mid-range active

short-arc motions can provide oscillatory inhibition and relaxation. If pain increases, the techniques are discontinued.

If symptoms are *minimally irritable* the primary goal of treatment is to assess for dysfunctions (characteristics of neuromuscular control) and to provide appropriate manual therapy (soft tissue and joint mobilization and neuromuscular reeducation).^{23,24}

Throughout the evaluation process, care must be taken to differentiate between the primary symptoms and those which are secondary to compensations, inflammation, and inactivity. Pain is rarely localized to the primary dysfunctional structure, partially due to the compensatory movement patterns and altered postures. These compensations, if chronic, precipitate muscular imbalances and strength loss. Secondary dysfunctions serve to reinforce the primary dysfunction and ultimately need to be addressed.

Example. Patients suffering from cervical pain and demonstrating restricted cervical movements, often have restriction of scapula patterns as well. Since the cervical spine and shoulder girdles share many of the same muscles, treatments of shoulder girdle dysfunction often have dramatic effects on cervical dysfunctions and symptoms. In addition, in highly irritable patients in which the cervical spine cannot be treated, the shoulder girdle may often be successfully utilized. As limitations in the scapular patterns are identified, HR, CR, or COI techniques can be applied to enhance relaxation. Muscle tension reduction may produce immediate changes in arthrokinematics, extensibility, and proprioceptive input of the shoulder girdle and cervical spine.^{6,57} Improved movement patterns often result in pain reduction. As compensations are resolved, the therapist can work directly into the primary dysfunction, much like peeling the layers of an onion.

Limited Functional Excursion and Muscular Imbalance

Dysfunctional effects occur secondary to limited myofascial excursion, muscle play, and muscular imbalance.^{6,21,22,58} Such effects are:

1) Greater susceptibility for muscle pulls or tears.^{9,59}

2) Altered primary fulcrum of motion—*an example* is seen when there is restricted extensibility of lower extremity muscles. This limits hip and pelvic mobility and places the primary fulcrum of motion in the lumbar spine. With moderate hamstring restriction the lumbar spine becomes the improper primary axis of motion during most forward-oriented tasks. In addition, with psoas restriction, efficient vertical alignment and weight attenuation is impossible and the hips are limited from contributing to backward bending activities.

3) Altered posture and normal mobility—this is observed in patients with limited functional excursion of the muscles of the cervical and upper thoracic spine. The following muscles are often the most frequently involved and most dramatically contribute to cervical pathomechanics: suboccipitals, scaleni, longus colli, levator scapulae, SCM, multifidus, pectoralis minor, posterior superior serratus, etc.

4) Joint dysfunction and pathomechanics—alterations in the excursion and mobility of either the myofascial unit or the articulation serve to facilitate or reinforce dysfunctions in the other.^{6,12,19}

5) Agonistic tightness inhibits antagonistic function.^{6,56}

6) Unilateral restriction increases emphasis for motion on opposite side.²⁰

Clinical Example. The utilization of PNF strategies can be effective for improving these types of conditions:

Many patients with lumbar symptomatology have marked anterior to posterior muscle imbalances (Figs. 11.15, 11.16). The trunk extensor and hip flexors have limited functional excursion, while the trunk flexors and hip extensors are weak, with sluggish or absent responsiveness. These patients often stand with the thoracic cage posterior to the pelvis, increasing the lumbar lordosis. During forward oriented functional activities, most of the motion occurs in the lumbar spine. This compares with the efficient state where the primary axis of motion occurs in the pelvis

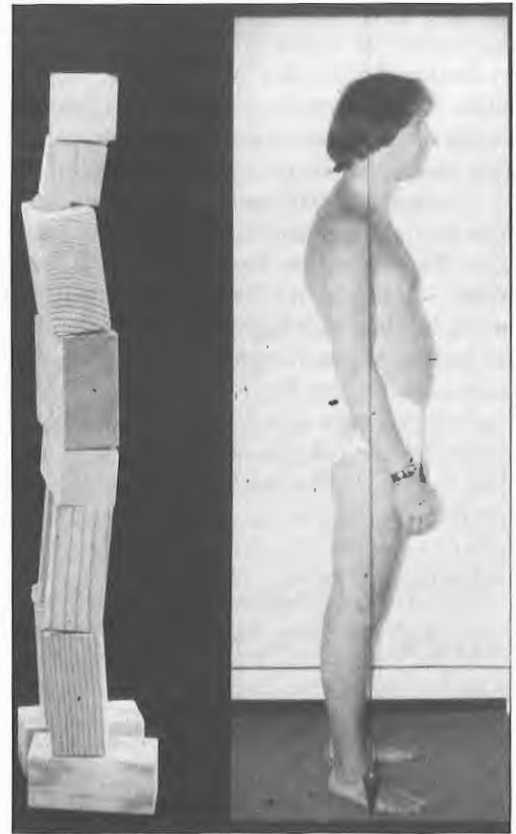


Figure 11.15. The frequently observed dysfunctional standing posture of thoracic cage posterior and backward bent in relationship to the pelvis often precludes inefficient movement patterns.

and hips, and minimal motion occurs in the lumbar spine (Fig. 11.17).

The initial focus of neuromuscular treatment is facilitating efficient pelvic girdle patterns. Both structural and neuromuscular components are evaluated and treated using the diagonal of anterior elevation and posterior depression. During the resisted motion of anterior elevation, the pelvis should move in a straight line in relationship to the body, while the lumbar spine remains in a stable anteroposterior position. To accommodate the motion occurring in the plane of the facet joint, the lumbar spine will sidebend to allow the pelvic motion. (See Figs. 11.18, 11.19).

For the anterior elevation pattern to occur



Figure 11.16. Existence of muscular imbalance of the trunk muscles leads to trunk instability, inefficient fulcruming within the spine, and inability to stabilize spine against external forces.



Figure 11.17. Muscular balancing allows the trunk to stabilize and the base of support to generate and translate the force.

efficiently, the lower abdominals, trunk extensors, body of psoas, and quadratus lumborum must perform in a coordinated sequence of contractions and elongations. The primary tools for treating dysfunctions in the pattern are *contract* or *hold relax* to increase mobility and *combination of isotonic*s to improve the proper sequencing of muscle recruitment and dissociation of the pelvic girdle from the lumbar spine. As the motion becomes integrated, lower extremity flexion can be resisted to develop synergistic lumbopelvic/lower extremity control. This is an important motion for the initiation and progression of swing through in the gait cycle.

The *posterior depression pattern* occurs along the same track of motion but requires efficient

antagonistic muscles function to develop coordination of pelvic/hip motions and dissociation of pelvic/lumbar motions. This is an important pattern for push-off during the gait cycle.

As indicated in the example, there is a correlation between soft tissue dysfunctions and the identified muscular imbalance. In many traditional manual therapy approaches, soft tissue changes have been treated as secondary dysfunctions and believed to be treated indirectly by joint mobilization. Often the soft tissues feel improved following joint mobilization. Therefore, it has been theorized that they do not need to be addressed separately. However, through a more dynamic palpatory assessment, the experienced therapist can often identify structural dysfunctions of muscle play,²¹ accessory mobility, and ex-



Figure 11.18. Pelvic anterior elevation.



Figure 11.19. Pelvic posterior depression.

tensibility, which the conventional evaluation will not reveal. Throughout the procedures of PNF these dysfunctions can be identified and normalized.

Motor Control

Assessment and treatment of inefficiencies in motor control should consider: elements of

recruitment, sequencing, coordination, balance, and fine motor control.^{10,15,32} Inefficiencies in these elements may be secondary to: altered arthrokinematics, soft tissue trauma, muscular tension, pain, CNS irritability, posture, or receptor damage.

Efficient muscle recruitment is the ability to initiate and grade a muscle contraction to the

appropriate internal and external demands of the environment. The neuromuscular system, in most cases, is trying to identify the most efficient and coordinated manner to perform tasks, but in dysfunctional states is unable to make the appropriate corrections. Through the use of techniques of neuromuscular re-education, the system experiences the more efficient and coordinated recruitment, and through the use of repetition and resistance the system learns this as a new option for movement. Recruitment can be assessed by varying the type, direction, and amount of resistance given, such as combination of isotonic or stabilizing reversals. If the patient's *recruitment is in excess* of demand, rhythmic initiation can be used, starting with passive and slowly progressing to the desired amount of recruitment. Inversely, when *recruitment is deficient* in meeting demand, the contraction can be augmented by reflex facilitation (repeated quick stretch, traction, or approximation). If the patient's selective recruitment is inappropriate and more responsive, overactive muscles substitute for the movement. Then the PNF patterns and COI (combination of isotonic) or hold relax techniques can be emphasized to ensure appropriate recruitment.

Sometimes the muscles are not recruited in an efficient order and there is an *altered pattern of motor sequencing*. In this case a repeated quick stretch can be applied to the latent muscle at the appropriate point in the range to facilitate more efficient recruitment patterns. Also, a combination of isotonic can be utilized, beginning with a maintained contraction in a range where all the components of the pattern can be recruited, and then through the use of eccentric and controlled concentric contractions, one can retrain the efficient pattern.

Inefficiencies in coordination, balance, and fine motor control can be addressed by reducing the task to its simplest and easiest component. These components are generally learned most efficiently in the least demanding positions and postures. As skill develops, they are progressed to the more complex functional postures, motions, and tasks.

Example. During lifting activities, patients often demonstrate inefficiency of mechanics, recruitment, balance, and motor control. Dysfunctions of these components can be effectively retrained by reducing the more complex activity into simpler components.^{10,13,15}

Initially, retraining of smooth and coordinated *weight shift* is accomplished through appropriate resistance to the pelvis. If the bipedal position is too premature, weight shift can be first trained in quadruped, half kneeling, or sitting (Fig. 11.20).

Proper *sequencing* of the hips and trunk, should occur with the primary motion occurring at the hips with trunk providing controlled stability. The proper coordination of the motion is often trained more effectively in sitting, then progressing to standing.

To train the proper use of the *base of support*, balance and control can be emphasized through the use of resistance. Once the



Figure 11.20. Resisted gait—used to retrain efficient weight shift.

smaller components are developed they are integrated back into the larger activity of lifting; the technique of combination of isotonics is used to effectively retrain the components into the whole throughout various portions of the task.

Segmental Limited Mobility

Treatment of limited mobility has been covered previously in this chapter. This section is designed to provide examples in the cervical, thoracic, and lumbo-pelvic regions.^{23,24} Segments with restricted mobility can be identified through:

- Restriction in range of a pattern,
- A section of the range in which the motion "jumps" past a region,
- A deviation in the performance of the pattern at a specific segment,
- Palpation of the spinal structures while the pattern is being performed.

The general principle for utilizing PNF to restore segmental mobility is to:

- Localize the restricted motion,
- Lock the segments above and below to provide specificity,
- Place manual contact upon the restricted region to provide a fulcrum and kinesthetic feedback.

If the localization is done well, many times substantial mobility can be gained through the use of selective breathing. The patient is instructed to breath into the manual fulcrum and build up to the point of comfort; then, on exhalation, to relax and allow a new range to be gained. Once the segment is moved into the new range, the technique is performed again until progress plateaus or normal mobility is reinstated. Facilitation techniques are then applied to reeducate the new range. If breathing does not provide adequate force, a hold or contract relax can be performed when the symptoms are not too irritable.

Cervical Spine. Each segment is evaluated for its ability to move both into flexion and extension within the patterns. In the flexion motion, the anterior aspect of the facet

joints are palpated for limited mobility. This is the region to which the treatment fulcrum is placed. In the same manner the posterior articular pillars are palpated into extension to that side. The options for facilitating a contraction are: breathing, use of shoulder girdle, jaw opening and closing, eyes movement, side-bending of the trunk specificity, or contractions within the pattern (Fig. 11.21).

Thoracic Spine. A frequently restricted motion in the thoracic spine is backward bending. The following procedure is adapted from a thoracic spine mobilization technique. The restricted segment is localized through a hand placed posterior at the level of restriction, and the resisted force is placed through the patient's elbows. The treatment technique is applied by having the patient lift the elbows up or down (Fig. 11.22). This will localize the force to the restricted movement segment. As the range increases, neuromuscular reeducation is performed in the new range. If a manipulative thrust is used, neuromuscular reeducation can help to retrain the surrounding muscles to functionally maintain the gains.

Lumbar. Through the use of standard localization techniques (see Fig. 11.23) instead of passive mobilization techniques, the more dynamic PNF approach can add a more functional option. *Hold relax* is often the technique of choice to assure the proper recruitment and avoid substitution or too forceful of a response.

Pelvic Girdle. Figure 11.24 illustrates the use of a position to dynamically mobilize and reeducate an innominate bone that is restricted into posterior torsion.

Instability

Spinal stabilization is the capacity of the intrinsic and extrinsic trunk musculature to provide both segmental and general stability to the spine in response to movement demands and external forces.^{13,32} This protective stability or lumbar protective mechanism^{36,44} requires adequate strength and responsiveness of the trunk musculature. Adequate strength includes both sufficient force production and



Figure 11.21. Cervical flexion pattern—used to evaluate the neuromuscular control and arthrokinematics of the cervical spine.

endurance, while responsiveness is the speed and appropriateness of the reflex reaction to external demands.

Segmental Stability. This is the capacity of primarily the one joint intrinsic muscles (i.e., in the lumbar spine the multifidi, rotatores, interspinales, intertransversarii, and the one-joint fibers of the quadratus lumborum and psoas) to provide controlled sta-

bility and mobility at each movement segment.

General Stability. This is the capacity of the multijoint extrinsic muscles (rectus abdominis, obliques, erector spinae, multijoint fibers of the quadratus lumborum and psoas) to provide controlled stability and mobility of the lumbar spine in relationship to the pelvis and thoracic cage.



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smaller components are developed they are integrated back into the larger activity of lifting; the technique of combination of isotonic is used to effectively retrain the components into the whole throughout various portions of the task.

Segmental Limited Mobility

Treatment of limited mobility has been covered previously in this chapter. This section is designed to provide examples in the cervical, thoracic, and lumbo-pelvic regions.^{23,24} Segments with restricted mobility can be identified through:

- Restriction in range of a pattern,
- A section of the range in which the motion "jumps" past a region,
- A deviation in the performance of the pattern at a specific segment,
- Palpation of the spinal structures while the pattern is being performed.

The general principle for utilizing PNF to restore segmental mobility is to:

- Localize the restricted motion,
- Lock the segments above and below to provide specificity,
- Place manual contact upon the restricted region to provide a fulcrum and kinesthetic feedback.

If the localization is done well, many times substantial mobility can be gained through the use of selective breathing. The patient is instructed to breath into the manual fulcrum and build up to the point of comfort; then, on exhalation, to relax and allow a new range to be gained. Once the segment is moved into the new range, the technique is performed again until progress plateaus or normal mobility is reinstated. Facilitation techniques are then applied to reeducate the new range. If breathing does not provide adequate force, a hold or contract relax can be performed when the symptoms are not too irritable.

Cervical Spine. Each segment is evaluated for its ability to move both into flexion and extension within the patterns. In the flexion motion, the anterior aspect of the facet

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Figure 11.22. Resisted trunk flexion and extension patterns are combined with thoracic joint mobilization.

Integration. These two components must work together in a coordinated pattern to provide adequate stabilization. The neurophysiological principle that normal timing occurs from proximal to distal applies to the spinal musculature. The intrinsic muscles should provide the initial contraction to stabilize the segment to prepare for the extrinsic demands of stability or mobility.

If there is inadequate spinal stabilization of a region or individual segment, those structures are more vulnerable to sustaining injury during stressful activities or trauma. They also will receive repetitive microtrauma during normal activities, particularly those performed with rotation or end-range positions. These segments often develop degenerative changes and become hypermobile from the



Figure 11.23. Hold Relax and Contract Relax techniques—used to facilitate lumbar mobilization; this treatment tool was later used in the development of

“Muscle Energy Techniques.” **A)** lumbar rotation; **B)** lumbar side bending while in extension and right rotation.

overstretching and demands to the discs, ligaments, and articular structures.^{6,20,60}

Posture

Another mechanism which precipitates instability is posture. In efficient posture the individual spinal structures are positioned so that weight is distributed to the base of support and force is attenuated through the structure.

However, many individuals have habitually developed postures which abnormally converge the weight distribution, force attenuation, and motion to individual regions and segments.

Example. A common postural dysfunction is the thoracic cage positioned in backwardbending in relationship to the lumbo/pelvic region. This posture creates an abnor-

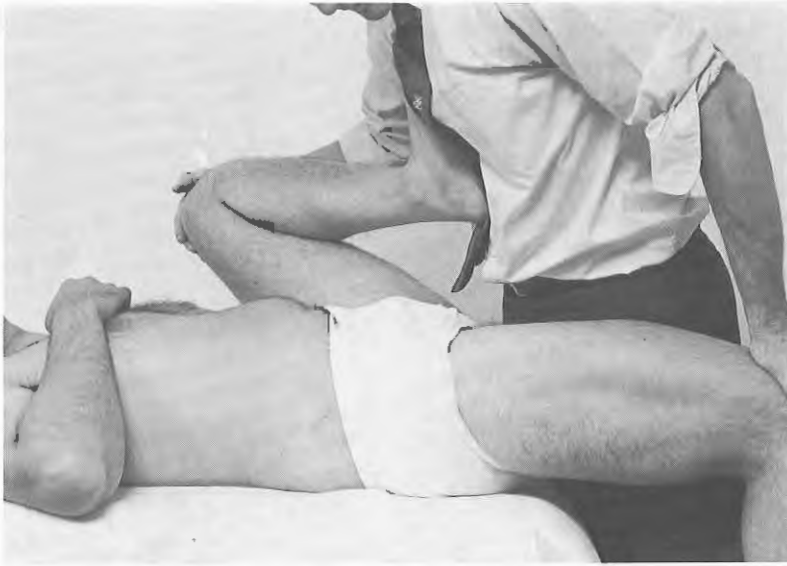


Figure 11.24. Use of contract relax to improve the mobility of a restricted innominate.

mal sharp angle (fulcrum) in the mid-lumbar spine, with the center of gravity shifting more to the posterior elements. During vertical loading this region will tend to buckle or bend backward, further stressing the posterior elements. In addition, the posture places the posterior myofascial structures in a shortened position and the abdominal muscles on stretch, altering the normal agonistic/antagonistic balance.⁶ The abdominals tend to become weak, over-stretched, and delayed in their responsiveness, while the extensors generally become shortened, with increased tone, and delayed responsiveness. The underlying movement segment progresses through the degenerative cascade.⁴ In addition, due to reduced motion demands the regions above and below usually develop some degree of hypomobility.

Tests

Efficient alignment can be assessed through the *vertical compression test*, where a vertical pressure (approximation) is placed to the shoulders and the stability of the spine assessed (Fig. 11.25).^{21,44} Regions where buckling is felt or seen are considered dysfunctional.



Figure 11.25. Vertical Compression Test (Johnson, 1984).

Responsiveness is tested through the *lumbar protective mechanism test* (Fig. 11.26). The test is administered with the patient in standing or sitting, while the therapist applies unidirectional pressure to the shoulders in posterior, anterior, and diagonal directions. The patient is instructed to hold, and the responsiveness and strength of the resulting contraction is graded. In the efficient state there is minimal lumbar motion.

Therefore, the treatment strategy for instability must address the structural, postural, and neuromuscular components.

Components

Structural. The soft tissue and myofascial dysfunctions need to be addressed through appropriate manual therapy techniques so the region has improved mobility and postural potential (Fig. 11.27).

Postural. Through graded and guided resistance and repetition the individual can be trained to attain an improved posture and to efficiently move in and from that posture. To assist their ability to maintain and their kinesthetic awareness of the posture, possibly through re-hiasing of the muscle spindles, stabilizing reversals are applied in the optimal posture.

Neuromuscular. Education and training are required to prepare a patient to efficiently respond to the external forces which necessitate a stabilization response. The neuromuscular element of the structural and postural dysfunctions is evaluated and treated for the integral role this system plays in posture and movement retraining. The philosophy and principles of PNF give the therapist the tools to retrain the neuromuscular elements to support the stabilization response.

The process of stabilization training or functional rehabilitation is an integrated process, which includes the gamut of manual therapy techniques. The interrelated use of PNF with soft tissue and joint mobilization allows the therapist to progress the patient

rapidly through the rehabilitation. Because the effects of structure and function are interdependent PNF may be used to address both aspects during the course of treatment, balancing one system as the other is altered through techniques.

Such utilization of PNF during the stabilization or functional rehabilitation program may include:

1. The use of contract or hold relax techniques as an adjunct to soft tissue mobilization to facilitate elongation in shortened muscles.

2. The use of trunk, shoulder girdle, and pelvic PNF patterns to localize the unstable segment and facilitate contractions of the intrinsic muscles. This is generally accomplished through the application of prolonged isometric and stabilizing reversals. The manual approach of PNF gives direct feedback to the therapist which is needed to assure proper recruitment is occurring. Otherwise, new movement patterns using old, habitual recruitment motor patterns are being retrained.

3. The use of combination of isotonic to manually reinforce and train controlled movement. This trains the extrinsic muscles to coordinate with the intrinsic muscles.

4. The next progression is to use the extremities in activities such as resisted rolling and crawling, while stability and control are maintained in the dysfunctional segment (Figs. 11.28, 11.29). This is coupled with an independent exercise program.

5. Progression to resisted functional activities such as lifting, walking, pushing, pulling, etc. is evaluated first through the manual principles of PNF, then trained and progressed to an independent exercise program (Fig. 11.30). Once again, the emphasis of PNF at this stage is to assure the patient does not substitute previous movement patterns during the more complex activities.

6. Balancing reactions through treatment adjuncts such as the Swiss ball (Fig. 11.31). Feldenkrais foam roll, balance boards, etc. offer the advanced training necessary to facilitate functional and spontaneous carry-over of stabilization to activities of daily living.

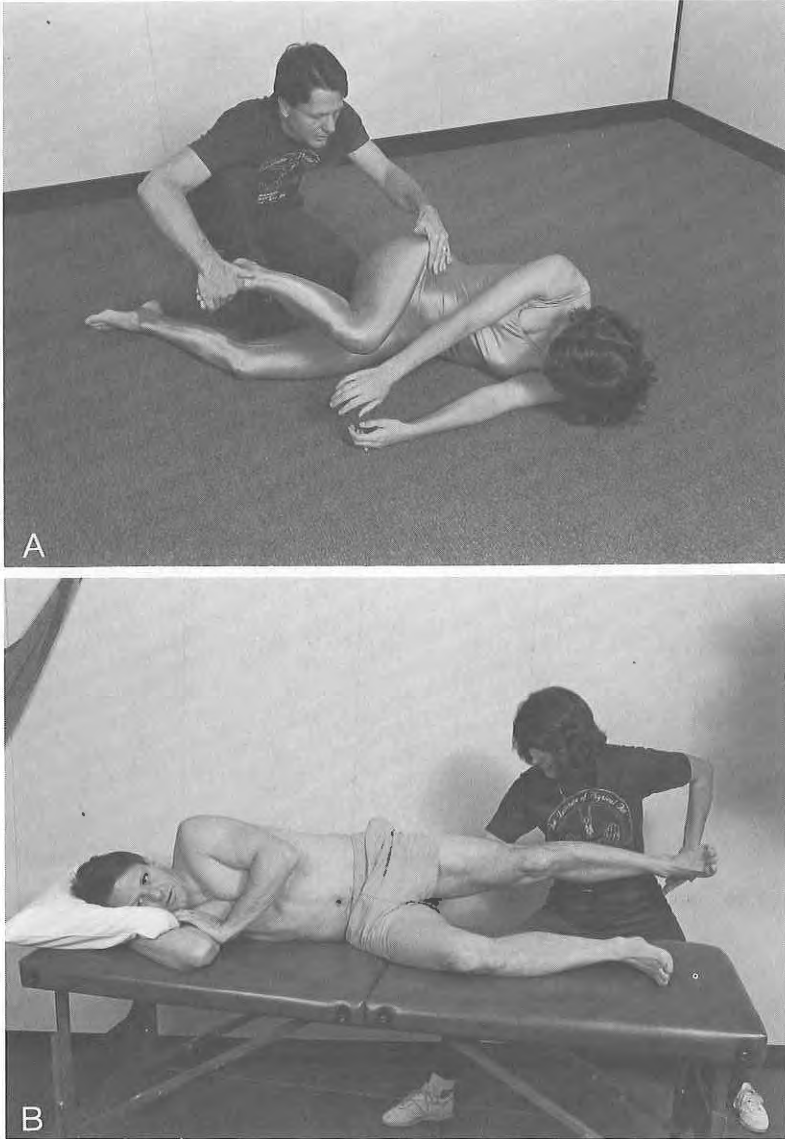


Figure 11.28. Use of lower extremities to facilitate rolling.

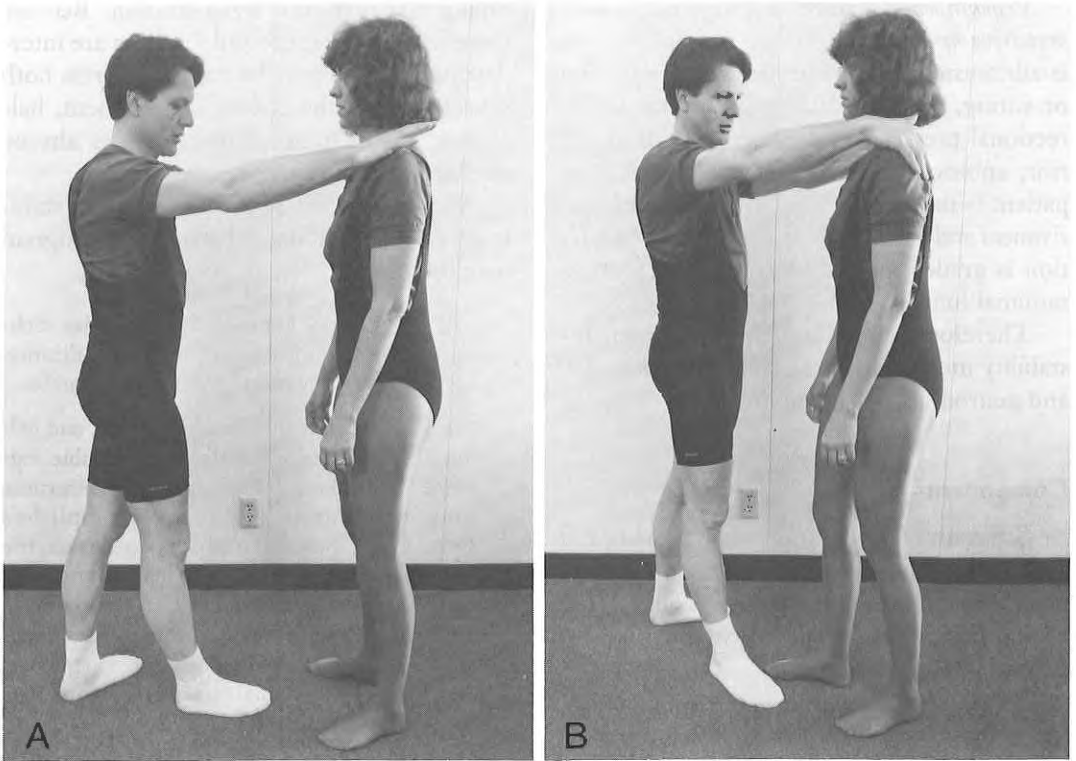


Figure 11.26. Lumbar protective Mechanism (Johnson, 1984). **A)** Flexors; **B)** Extensors.



Figure 11.27. Soft Tissue Mobilization technique (Johnson, 1978).



Figure 11.29. Facilitation of crawling—through resistance and facilitation to the extremities.



Figure 11.30. Resisted functional activities to ensure appropriate motor recruitment.

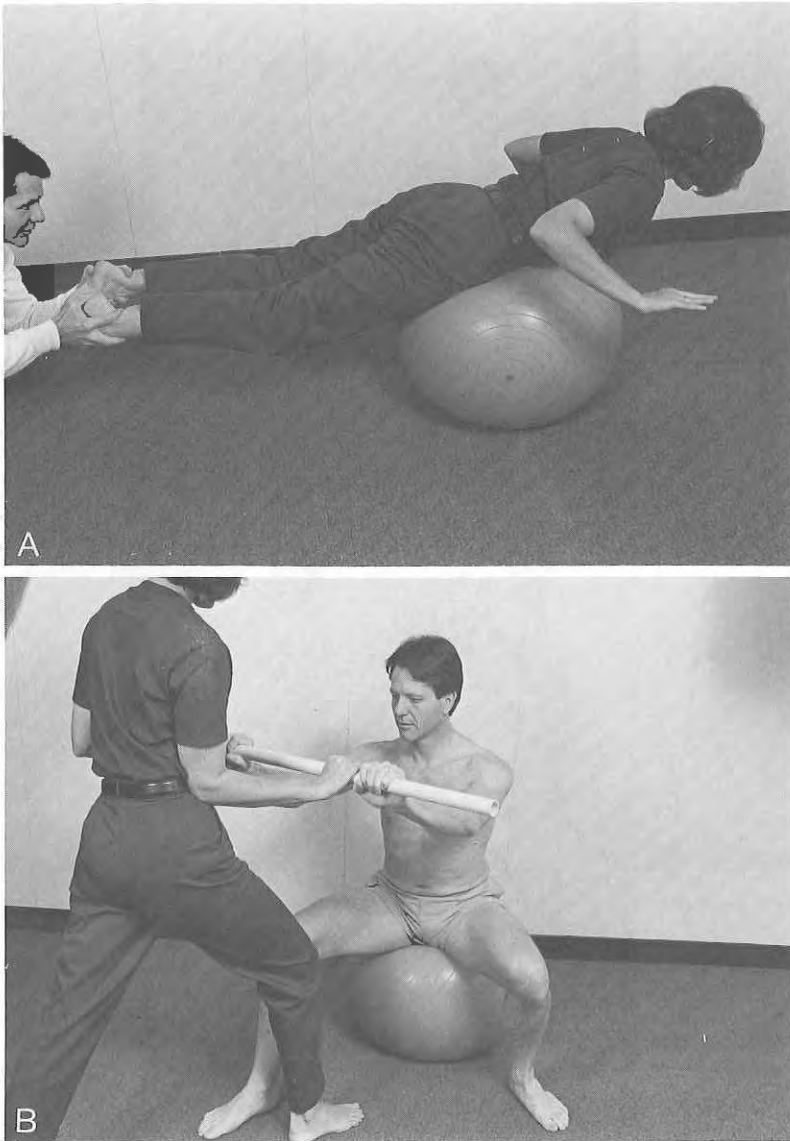


Figure 11.31A & B. Use of PNF facilitory techniques to enhance responsiveness training while working on the Swiss Ball.

CONCLUSION

The ability of a therapist to clearly assess the underlying structural and/or neuromuscular dysfunctions which perpetuate an identifiable alteration in a person's functional activities of daily living is the foundation of physical therapy. This ability is enhanced by the understanding and utilization of the manual therapy approach of Proprioceptive Neuromuscular Facilitation. Through the principles, procedures, and techniques of PNF the therapist can identify and treat many of these structural and functional aberrations. In addition, the approach of PNF allows the therapist to fully integrate the treatment of structure and function by continuously integrating structural changes into functional improvements. The results achieved through structural techniques such as soft tissue mobilization and joint mobilization are enhanced when incorporated into the neuromuscular system.

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