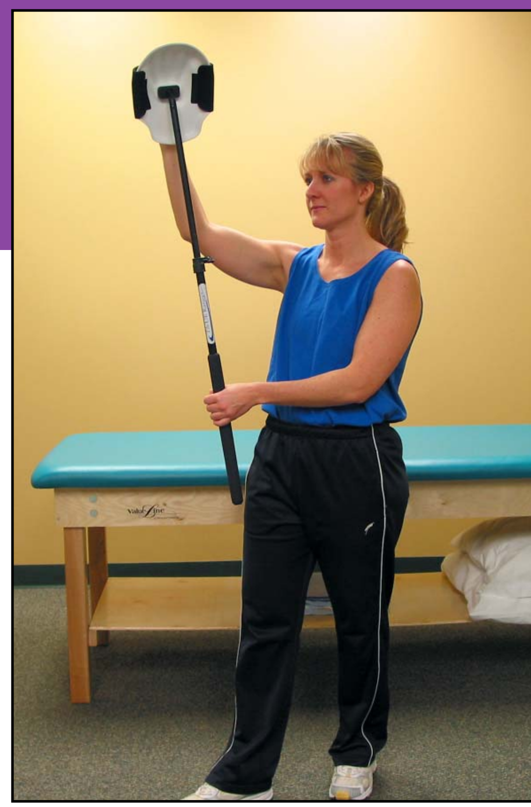
The Complexity of Healthy Movement

In Search of the Science and Therapeutic Values Within Assisted Movements of the Upper Extremity



By Dan S. Miller PT, MS

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Physical impairments of the musculo-skeletal system such as pain, weakness, and altered joint properties can contribute to the development of pathological movement patterns and lead to the deterioration of functional capacity (1, 2).

Healthy movement of the full upper extremity (UE) kinematic chain relies on subtle and complex neurophysiological and biomechanical relationships. Aberrant movement patterns and postures are obvious to and well-defined by clinicians who manage patients with musculoskeletal pain. Substitution patterns or pain avoidance strategies such as excessive scapular vertical motion, listing of the spine, and decreased range of motion are often observed (1, 3, 4, 5).

CLINICAL PRESENTATION

Other impairment changes are not as readily apparent. Research beginning in the early 1990s has revealed a greater understanding of the effects of musculoskeletal pain on motor activity and control. (1,2,3,5,6,7) Studies have shown that the presence of pain leads to inhibition or delayed activation of specific muscles or muscle groups that perform key synergistic functions (1,2). This produces alterations in the patterns of motor activity and recruitment during functional movement. Researchers have suggested that this inhibition usually occurs in the deep muscles local to the involved joint that perform a synergistic function to control joint stability (1).

A functional study has demonstrated that induction of experimental pain in the Upper Trapezius muscle adversely influenced shoulder muscle coordination and instigated a reorganization of the pattern of muscle recruitment (6). Kibler (7) considered the Serratus Anterior and Lower Trapezius muscles to be susceptible to inhibition in painful shoulders. Kibler used the term “scapular dyskinesis” to describe the resultant presentation of disorganized normal muscular firing patterns and a decreased ability to produce torque and stabilize the scapula.

Due to its inherent structural instability, muscles and ligaments are the primary stabilizers of the glenohumeral joint. Combine this stabilizing requirement with its contribution to the vast functional ability of the shoulder joint complex, and the magnitude that neuromotor reeducation holds in the pursuit of restored healthy UE movement is evident. Efficient healthy movement, the postural control of alignment, and balance of the dynamic body require more than adequate force production from the muscles. These complex muscle actions must be precisely coordinated to occur at the correct time, for the correct duration, and in the correct combination of forces. This coordinated action occurs within groups of synergistically acting muscles and extends to agonist-antagonist muscle interactions. It requires sensory, biomechanical, and motor-processing strategies along with learned responses from previous experience. (4, 8).

TRADITIONAL SHOULDER GIRDLE REHABILITATION

For the purpose of this discussion we will consider a person who has recently undergone an arthroscopic repair of a torn rotator cuff and was immobilized for seven days. Per traditional protocol as described by Neer (9), this hypothetical patient has transitioned through the latter stages of phase I, or Passive Range of Motion (PROM) and is transitioning into phase II, or Active Assisted Range of Motion (AAROM).

The physiological influences and therapeutic benefits of PROM protocols are well understood and accepted as involving some external force to initiate movement. They therefore, by definition, minimize muscle activity of the involved shoulder (10). Varying protocols have been studied to determine the success of adhering to this definition. These studies concluded that use of pulleys or a self–supported bar raise i.e. cane, broom handle, or other rigid bar will not help a patient to accomplish true PROM (11, 12).

In the progression from PROM to AAROM, tissue healing is generally incomplete and the musculotendinous-boney tissue repair cannot tolerate high tensile strains, from either externally or internally generated force. The patient is often anxious to start moving the arm again and will generally use substitutions to perform active motions in order to achieve a semblance of normal UE function (13).

An important capacity of normal function is to dissociate different body parts during movement. (7, 14, 15, 16) For an injured shoulder, the inability of the humeral head to articulate in the glenoid socket, independent of scapular motion, in the initial stages of movement is a failure to dissociate one joint from another, and a potential sign of a motor control deficit substitution. (4, 5) Feldenkrais used the term "superfluous effort" to describe the excessive work and energy requirements in such a dysfunctional movement (15). Detecting substitution strategies and consequent provocation of symptoms requires careful attention (5). Allowing a substitution to become established can contribute to a plethora of negative physiological and biomechanical consequences within the shoulder complex and in the cervicocranial and thoracocostal vertebral complexes. Biomechanical and physiologic loads placed on the shoulder musculature during this period should stress tissue enough to facilitate strength and increase motion while not allowing abnormal movement patterns or overloading the tissue, thereby producing a deleterious inflammatory response (13). A more obvious negative outcome of excessively overloading the repaired tissue might be a disruption of the rotator cuff repair. This means that the intrinsic muscle activation intensity should be low initially, progressing to higher levels over time, and that extrinsic loads should be controlled in a similar manner. Starting with a short lever arm during an arm elevation activity and progressing to activities using a longer lever arm is one way to adjust the extrinsic load (13, 16).

Instruments currently available to support this critical transition in rehabilitation on the part of the patient and his or her treating therapist include a self-assisted pulley system; a self-assisted rigid bar (i.e., a cane, T-bar, or broom handle); wall slide and slant boards; and the newly introduced UE Ranger

Though there is widespread application of these instruments, research into the most efficient means of meeting the needs and challenges of persons with upper extremity motion limitations has been limited thus far (11,12,13,17)

DISSECTION OF THE SUBTLETIES OF ASSISTED MOVEMENTS

A review of the relevant research will help practitioners to critically evaluate the actual dynamics of each of the assistive instruments noted above, and to consider their possible influences on the relearning of motor control. While it is acknowledged that this first study was designed to investigate the preceding level (PROM) of rehabilitation, its findings offer insight into the level of force that can be introduced to a healing structure and the challenges that exist in balancing a gradual progression from PROM to AAROM.

Dockery et al (11) evaluated rehabilitation protocols using EMG analysis of the rotator cuff muscles to determine their ability to promote passive elevation motion in healthy volunteers. Of relevance to this discussion was that most of the subjects, being familiar with both the rehabilitation protocols and the correct technique for using a pulley system and or a self supported bar raise demonstrated some of the difficulty that exists in trying to perform these exercises passively. The subjects described their efforts as very difficult if not impossible to perform passively. The pulley exercises were particularly difficult when the subject attempted to lower the study limb passively. The authors acknowledged that while the statistical differences between the maximal voluntary contraction (MVC) for pulley and self-assisted bar exercises compared with continuous passive motion (CPM) were real (17.6% and 8.7%, respectively), the actual muscle activity as a percent of maximum voluntary contraction was small**.** The relevant point to remember, however, is that postoperative patients would likely recruit greater than 18% MVC secondary to pain and apprehension (11).

Sporrong et al (18), demonstrated in nine healthy subjects the alterations in shoulder muscle EMG activity when they volitionally performed gripping activity of 30% to 50% MVC in sagittal (humeral flexion) and (frontal abduction) planes. The Supraspinatus muscle had a significant increase in EMG activity from 60º of flexion and 120º of abduction and above. In the Supra- and Infraspinatus muscles there was a positive correlation between the degree of the shoulder muscle activity and the intensity of handgrip exertion in most of the tested arm positions. The report of this study did not provide the percentage of MVC for either the Supraspinatus or Infraspinatus muscles, rather it was the author's acknowledgment of the complexity of the interaction between handgrip activity and shoulder muscle activity. It was reported that the stabilizing muscles (rotator cuff) were more influenced than the motor muscles (Deltoid and Trapezius) by hand activity. It was the author's opinion that these findings related to the rotator cuff were clinically relevant as they suggest vulnerability to an early onset of fatigue, with resultant potential for instability.

In both pulley systems and the various forms of self-assisted bar raises, patients are required to grasp the apparatus with their involved hand in order to execute the protocol. Whether the forces elicited by the shoulder muscles via this act of gripping are sufficient in themselves to warrant concern about excessive tensile forces at the repair site is unknown. Even less understood is what impact the simple grip requirement may have on the overall goal of incrementally restoring neuromotor control and proprioception (19).

Motor activity resulting from gripping is essentially a cocontraction of the muscles within the hand, the muscles that cross the wrist, and probably the muscles controlling forearm supination and pronation. It is an accepted principle that a cocontraction results in stiffening at the surrounding joints (20).

At first glance, this cocontraction of the distal segments of the kinematic chain may act as a constraint on the multijoint system and reduce the degrees-of-movement freedom required for a smooth, coordinated multi-joint, functional motion, such as elevation. (4,21,22,23) An effort on the part of a patient or an athlete to practice the teachings of his or her physical therapist, occupational therapist, or athletic trainer; e.g., dissociation of movement, is countered by the following potential deleterious effects:

- altered afferent input, affecting the ability to perceive inter-segmental dynamic joint relations and re-education of motor control. (5,8)
- Excessive energy consumption due to the increased work needed to overcome this biomechanical resistance (15, 24)
- Promotion of altered arthrokinematics and arthrokinetics; (15, 16)
- Unnecessary pain (4) and
- Reduced motor neuron excitability of the rotator cuff (force couple mechanism) secondary to substitution (5, 25)

MECHANICAL SUPPORT OF THE SCIENCE OF MOVEMENT

In comparison, The UE Ranger is designed to support the hand of the involved upper extremity in a molded support that accommodates the left or right hand in a resting position. Combined with the securing strap **(Figure 1)**, this feature eliminates the gripping requirement and the potential negative influence of superfluous muscle activity elicited at the rotator cuff. Eliminating motor recruitment other than that required for the balance of dynamic stabilization and initiation of movement enables the patient to sense an accurate and appropriate progression of motor activation for a given movement.

Figure 1

Schmidt and Winstein (26, 27) indicated that in efforts to retrain motor control, the patient should gain the sensory awareness and the volitional ability to activate the deep stabilizers before trying to activate the more superficial torque-producing muscles. Failure of the stabilizing function of the rotator cuff force couple may lead to creation of an abnormal axis of rotation and abnormal translation of the humeral head (5). This failure may occur in any plane or point within the patient's currently available ROM.

Successful resolution is facilitated in part by the patient's ability to reestablish volitional control of this force couple. It has been advocated that training begin in positions of control, as close to the position where that control is lost as possible (5). Isometric and isotonic training can be undertaken concurrently, as long as the patient is aware of the different sensations associated with control and lack of control (5). In a progressive sequence, the UE Ranger supports the capacity to integrate this stabilizing muscle activity into a complex multijoint movement.

The UE Ranger is designed to enable the patient to self-assist the supported involved upper extremity with the non-involved upper extremity. The UE Ranger combines the capacity to support movement dissociation of the inter-segmental joints with load and direction control in the pursuit of multiple functional planes of motion. This is made possible by the articulating rubber joint, which secures the molded hand support described above to the telescopic guidance tubing **(Figure 2)**. These relational capacities enable the patient to initiate from a stationary position **(Figure 3)** a smooth progression of motor control in relation to appropriate levels of intrinsic and extrinsic load progressions. This capacity allows introduction of varying functional demands; i.e., full body reaching with increasing moment arms and speed of movement to be blended with appropriate support and progression of endurance **(Figure 4)**.

Figure 2

Figure 3

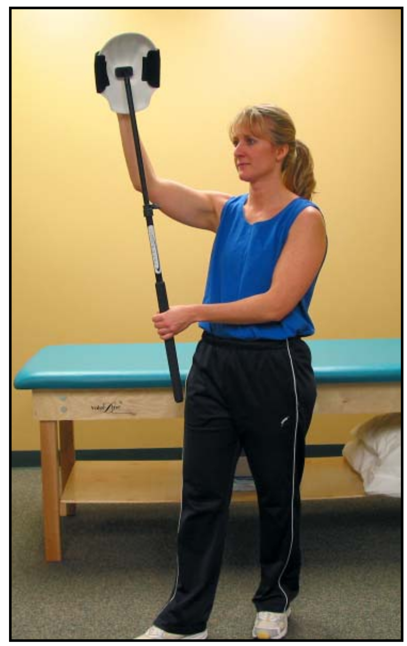

Figure 4

A common barrier to progressing rehabilitation is the influence of pain, particularly at a patient's current end range (10). This barrier can be related to intersegmental joint alignments and related soft tissue stresses, including joint compression forces. The capacity of a patient to articulate the wrist and forearm, independent of shoulder movement, fosters the patient's own control of pain reduction by alleviating mechanically induced stressors. This capacity additionally enables the patient's soft tissue restrictions to be isolated and addressed. Releasing the restrictions and lengthening the tissue requires that it be held at the end range. If this is painful, the patient generally will not be able to tolerate the stretch long enough to effect a lasting tissue change.

An additional difference between the UE Ranger and other assistive devices described is the capacity of a patient to explore multiple combined planes of motion, while simultaneously being supported through an articulating distal base plate support, and nonskid pad **(Figure 5)**. This feature provides mechanoreceptor and neuromotor stimulation in response to the forces associated with closed kinematic chain movements (14, 28) Depending on the alignments between the joint segments of the upper extremity kinetic chain, simulation of varying occupational-, sport-, or ADL-specific demands can be reproduced. This reproduction can simulate motor activity associated with both generating and reducing forces while supporting the unstable shoulder in such activities. This capability also relieves the noninvolved upper extremity of its assisting role, and therefore allows a natural graded progression of motor control and movement away from the body by the involved limb **(Figures 6, 7)**.

Figure 5

Figure 6

Figure 7

CLINICAL IMPLEMENTATION

In order to test the merits of the UE Ranger, Rehab Innovations, Inc. and The Praxi Group, an independent research firm based in Evergreen, CO implemented a limited market trial of this device.. The primary function of this trial involved placing the UE Ranger with a number of orthopedic physical therapists (OPTs) for use with their patients for whom the specific treatments targeted by the UE Ranger are involved.

A total of 46 OPTs were recruited for participation in the limited market trial: 43 from Nebraska and western Iowa and three from a select nationally representative group.

OPT respondents were requested to respond to a series of qualifying questions vetted to confirm their qualification for the trial and their willingness to participate. Candidates were required to be actively practicing in an orthopedic clinical environment and be personally providing treatment for patients with current shoulder girdle pathologies related to the neuromotor, and or musculoskeletal systems. Candidates were required to be proficient and currently utilizing at least 2 of the following 6 clinical interventions:

1. Active Assistance of Joint Range of Motion
2. Active Assistance of Soft Tissue Mobility
3. Passive Joint Range of Motion
4. Functional Multi-plane Self graded Strengthening
5. Proprioceptive Neuromotor Re-education (PNF)
6. Kinematic Chain Biomechanics

Potential participants were provided with an overview of the UE Ranger's design and intended benefits, detailed instructions for its use, and the objectives of the market trial (potentially including specific areas of learning and questioning).

The respondents agreed to implement the UE Ranger into the appropriate treatment interventions for a period of six months based on their perceptions of the product's benefits relative to existing alternatives, and also agreed to provide debriefs of their experiences with the product via follow-up surveys and/or telephone interviews. As part of their agreement to participate, the OPT respondents signed legally binding nondisclosure agreements and liability release documents. Additionally, the respondents were provided with liability release documents to be signed by the patients they proposed to treat with the UE Ranger.

As an incentive to participate in the trial, the OPT respondents were allowed to keep and use the prototype device free of charge and were also provided with a copy of the written report(s) of the research results. .

Following the six-month trial period, respondents were contacted by e-mail to confirm that the UE Ranger had been adequately tested (in terms of number of implementations) and to direct their attention to the quantitative follow-up questionnaire. Respondents were then mailed the quantitative questionnaire along with a postage-paid return envelope and asked to complete the survey within –two weeks.

A total of 37 returned questionnaires were edited for logic and completeness and then tabulated and analyzed by The Praxi Group.

The UE Ranger was rated by the OPTs as superior to pulleys and rigid wands for the following aspects of rehabilitation:

- attaining safe and relaxed passive assisted range of motion;
- restoring correct neuro-motor biomechanics through AAROM;
- being patient friendly in both open and closed kinetic chain planes of functional motion;
- improving patients' ability to reduce their pain through current end ranges of motion themselves;
- encouraging positive carry over between treatments, when used with home program; and
- achieving higher overall quality of care.

REACHING THE FUTURE

A full report of this clinical trial is available upon request. The information revealed from this study, has contributed to both structural improvements of the UE Ranger system and clarification of the most appropriate clinical application of the device. Additionally this study has highlighted the therapeutic values within the capacities of the UE Ranger as compared to traditional assistive devices. It is however acknowledged that this study is not without limits. The information requested of these participants was intentionally broad in scope, as a means of receiving feedback on multiple interests. In the future as a means of achieving the greatest understanding of the full value within the application of assistive motion devices, it would be recommended to reduce the scope of the investigation to isolate for example a particular post operative diagnosis, and the critical stage of transitioning from PROM to AAROM. It would also be a great value to measure objectively the electrical motor activity of a particular group of individual muscles through an EMG study. Further a motion analysis designed to isolate both potential destructive biomechanics as well as the capacity to support normal biomechanics offers potential real evidence of the variability between the alternative assistive devices.

Clinical interventions designed to support the reeducation of motor control are of extreme importance in the quest to fully restore healthy movements of the upper extremity. Understanding the science associated with relearning motor control and biomechanics is imperative to the short- and long-term successes of the rehabilitating patient. It is hoped that further research will be undertaken to examine the neurophysiology and biomechanics associated with assisted active movements. A critical evaluation of the current instruments designed to support AAROM offers an invaluable advancement in the capacity to restore healthy movement and function.

"When activity is freed of tension and superfluous effort the resulting ease makes for greater sensitivity and better discrimination, which makes for greater ease of action" (15).

Dan Miller, PT, MS is president of Rehab Innovations, Inc based in Omaha, Nebraska, and the developer of the UE Ranger further information regarding the UE Ranger is available at www. ueranger.com

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