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A Kinetic Chain Approach for Shoulder Rehabilitation

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Objective: To introduce an approach to shoulder rehabilitation that integrates the kinetic chain throughout the rehabilitation program while providing the theoretical rationale for this program.

Background: The focus of a typical rehabilitation program is to identify and treat the involved structures. However, in activities of sport and daily life, the body does not operate in isolated segments but rather works as a dynamic unit. Recently, rehabilitation programs have emphasized closed kinetic chain exercises, core-stabilization exercises, and functional programs. These components are implemented as distinct entities and are used toward the end of the rehabilitation program.

Description: Kinetic chain shoulder rehabilitation incorporates the kinetic link biomechanical model and proximal-to-distal motor-activation patterns with proprioceptive neuromuscular facilitation and closed kinetic chain exercise techniques. This approach focuses on movement patterns rather than isolated muscle exercises. Patterns sequentially use the leg, trunk, and scapular musculature to activate weakened shoulder musculature, gain active range of motion, and increase strength. The paradigm of kinetic chain shoulder rehabilitation suggests that functional movement patterns and closed kinetic chain exercises should be incorporated throughout the rehabilitation process.

Clinical Advantages: The exercises in this approach are consistent with biomechanical models, apply biomechanical and motor control theory, and work toward sport specificity. The exercises are designed to stimulate weakened tissue by motion and force production in the adjacent kinetic link segments.

Key Words: glenohumeral joint, closed kinetic chain, scapula, exercise, function

The goal of most athletic rehabilitation is to return the athlete to the activity that caused the injury. Successful shoulder rehabilitation depends on an understanding of the cause of injury and a complete and accurate diagnosis of the involved tissues. Therefore, a thorough understanding of the physical demands of the activity is a prerequisite to making a complete diagnosis and returning the athlete to safe, pain-free participation.[1] The kinetic link model, a biomechanical model used to analyze many sport activities, depicts the body as a linked system of interdependent segments, often working in a proximal-to-distal sequence, to impart a desired action at the distal segment.[2,3] This model illustrates the contribution of the entire body during sport activities rather than focusing on the action of individual segments. Normal, efficient motion and muscle activation are believed to occur in a proximal-to-distal sequence.[2,4,5] This proximal-to-distal sequencing should be considered when attempting to restore function via a rehabilitation protocol.

The shoulder pathology is the primary factor that determines the therapeutic treatment. Traditional shoulder rehabilitation after injury includes a phase of rest, control of inflammation, and isolated muscle strengthening.[6,7] Additional components of shoulder rehabilitation programs are scapular-stabilization, proprioceptive, and closed kinetic chain exercises. However, these exercise regimens tend to isolate the involved tissue initially while neglecting the contributions of the trunk and lower extremity.[8–11] Clinicians recognize the need to address the legs and trunk as contributors to shoulder function and for general conditioning, but their protocols often integrate the shoulder with the rest of the body late in the rehabilitation process.[6,7] In kinetic chain shoulder rehabilitation, the legs and trunk are integrated into most of the shoulder exercises from the onset. This reinforces normal movement patterns and reduces the challenge of learning new movements during rehabilitation.

We present an approach to shoulder rehabilitation that integrates the kinetic link model and normal synergistic muscle-activation patterns with proprioceptive neuromuscular facilitation (PNF) principles. Rather than isolating the shoulder and gradually incorporating the rest of the body, this approach focuses on rehabilitating the entire neuromuscular system by integrating multiple body segments throughout the process. The segmental integration follows the proximal-to-distal movement and muscle-activation sequence consistent with biomechanical upper extremity function.[2,5] Clinically, kinetic chain rehabilitation has been effective in restoring shoulder function when other methods of shoulder rehabilitation have failed.

THEORETICAL FOUNDATION

A common biomechanical model for striking and throwing sports is an open-linked system of segments that work in a proximal-to-distal sequence.[2] The goal of these activities is to impart a high velocity or force on the distal segment. The distal segment may be the hand of a pitcher, the foot of a soccer

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athlete, or the hand and racquet of a tennis player. The ultimate velocity of the distal segment depends on the velocity of the proximal segment and the interaction of these segments.[12–14] The proximal segments, the legs and trunk, accelerate the entire system and sequentially transfer the momentum to the next distal segment.[2] Conservation of momentum explains this segmental interaction. The equation for angular momentum is segment inertia times its angular velocity.[13] The initial acceleration of the proximal segment encompasses all the distal segments as part of its inertia. The sequential deceleration of the proximal segments conserves momentum by transferring segmental velocity distally along the kinetic chain.[2,13] This proximal-to-distal linkage provides an efficient and effective system to transfer force and produce greater velocity in a distal segment. Kinetic chain rehabilitation incorporates this model by initiating shoulder exercises through proximal segment movement.

Normal motor patterns of voluntary upper extremity movements while standing include lower extremity and trunk muscle activation before the arm motion.[4,5] Voluntary movements of the upper extremity, such as rehabilitation exercises, are primarily task oriented and are controlled via motor programs.[15–17] Motor programs are thought to exist for categories of movements, such as walking or throwing, rather than each component of a movement having its own program.[17] Motor programs use coordinated groups of muscles and joint movements, or synergies, often in a proximal-to-distal fashion, to simplify and perform movement tasks.[4,5,18] Kinetic chain shoulder exercises employ these natural motor programs by focusing on the neuromuscular system rather than on isolated movement and muscle activation. This method uses and restores normal movement patterns that are familiar to the neuromuscular system so the rehabilitation occurs within the framework of normal function.

Upper extremity motion follows this proximal-to-distal motor program sequence. Upper extremity motion occurs with consistent synergistic muscle activation patterns in the legs and trunk.[4,5,19] The task of rapidly reaching forward with the right hand to shoulder level produces a consistent pattern of activation and deactivation of leg and trunk musculature before activation of the anterior deltoid.[5,19] This sequential pattern includes deactivation of the left soleus, activation of the right tensor fascia lata and rectus femoris, activation of the left semitendinous and gluteus maximus, and, finally, activation of the right erector spinae before initial deltoid activity.[5] Injury at a distal segment can alter this proximal-to-distal control. Proximal hip muscle activation is delayed in patients with severe ankle joint injury compared with noninjured controls during hip active extension.[20] The possibility that injury to a distal segment alters normal motor programs further supports the need to incorporate these motor programs throughout the rehabilitation process.

The anticipatory patterns of leg and trunk activation are associated with segmental joint accelerations that effectively move the center of gravity forward and up toward the side of unilateral shoulder flexion.[5] These proximal-to-distal synergies are postural adjustments to counteract the disturbance in equilibrium caused by the voluntary arm movement.[4,5,21] This pattern of proximal muscle activation before distal movement serves as a foundation for using the trunk and legs to drive the scapula and shoulder during the rehabilitation process.[4,5,21] Kinetic chain rehabilitation incorporates these synergies to produce motion and activate involved muscles throughout shoulder rehabilitation.

Shoulder rehabilitation programs incorporate PNF techniques to stimulate synergistic patterns of movement.[7,22] Kinetic chain rehabilitation incorporates 5 important PNF concepts. The first is that motor behavior is a sequence of total patterns incorporating the head, neck, trunk, and extremities. This is true whether the movement is unilateral, bilateral, or reciprocal.[23] Motor behaviors such as baseball pitching or tennis serving illustrate this concept by generating maximum shoulder internal rotation through the transfer of forces from the legs, through the trunk to the shoulder. Second, normal goal-directed movement and posture depend on synergies to balance muscular activity between antagonists. Third, normal motor development occurs in a proximal-to-distal direction. Fourth, in movement patterns, stronger component patterns augment weaker components by the irradiation reflex,[23,24] which suggests that as the intensity of an applied stimulus increases, the area of response increases.[25] In kinetic chain shoulder rehabilitation, thoracic extension can stimulate scapular retraction. Applying resistance to thoracic extension should increase this stimulus and elicit an increase in the scapular retraction. Fifth, the clinician helps the athlete relearn the normal movement patterns by selecting and applying appropriate stimuli such as positioning, manual contact, or resistance. The clinician becomes part of the exercise environment by giving visual, auditory, and tactile feedback.[23,24]

RATIONALE FOR KINETIC LINK REHABILITATION

Kinetic chain rehabilitation approaches the shoulder as part of a kinetic link system and attempts to address shoulder function in a proximal-to-distal manner.[4,5,23,26] The proximal trunk segment, rather than the more distal arm, acts as the "initiator" for appropriate shoulder motion. Based on this proximal-to-distal premise, quality arm elevation and shoulder function depend on trunk and scapular control.[2,4,5,19] Trunk and scapular control exercises begin at the onset of therapeutic exercise in kinetic chain shoulder rehabilitation, since neither depends on arm motion. If the goal of an exercise activity is scapular movement, arm elevation is not required. However, scapular motion and control are prerequisites for proper arm elevation.[27,28]

Kinetic chain rehabilitation applies elements of biomechanical and motor control theories to PNF and closed kinetic chain exercise techniques. By using multiple body segments in the exercises, adjacent segments can facilitate the activation of involved muscles to develop appropriate shoulder motion and function (irradiation).[23–25] Adjustments of posture and the amplitude of movement by proximal segments can control the location and intensity of the loads of a given exercise. Early in the rehabilitation, the shoulder may require a great deal of facilitation, so the role of the adjacent segments may be exaggerated. Decreasing the role of the facilitating segments later in the progression increases the load and functional demand on the shoulder.

Successful acquisition of movement patterns is feedback sensitive and requires consistent observation to avoid compensatory movements.[23,24] The training of movement patterns, rather than isolated muscles, often requires verbal and tactile feedback. This immediate feedback may help the athlete to identify and correct movement errors. Gradual removal of the feedback is a form of exercise progression as the athlete gains awareness of appropriate and inappropriate movement patterns. The exercise goal is to find movement patterns the athlete can perform successfully while progressively loading deficient tissue anywhere in the kinetic chain.

Imbalances in the action of scapular force couples may result in scapular dyskinesis (abnormal scapular movement), glenohumeral translation, or rotator cuff overload. The function of the shoulder complex depends upon muscular force couples about the scapula and glenohumeral joint. Synergistic scapular muscle actions allow proper positioning and stability of the scapula while maintaining the glenohumeral center of rotation throughout arm motion.[29–31] Due to its anatomical location on an ellipsoid thorax, normal scapular motion is multiplanar.[27,32,33] Scapular motion provides optimal muscle length-tension ratios and reduces the muscular energy requirements of the rotator cuff during arm motion.[30,34] Scapular function mediates the demand on the rotator cuff, promotes energy conservation in the upper extremity, and aids in glenohumeral stability.[28,29,34]

Appropriate scapular motion requires attention to muscular flexibility. The upper trapezius and the pectoralis minor are common sites of myofascial tightness and hypertonia in athletes with shoulder pain and can limit normal scapular motion.[35,36] Throwing athletes commonly present with muscular tightness in the external rotators of the shoulder.[37,38] Tightness of the posterior capsule and decreased infraspinatus and teres minor flexibility can create excessive tilting of the scapula into protraction when the glenohumeral joint internally rotates at 90° of abduction.[39] These areas of inflexibility may be detrimental to scapular control and mobility. The kinetic chain exercises can aid in attaining flexibility, but stretching, massage techniques, therapeutic modalities, or joint mobilizations may be necessary.

Scapular dyskinesis is often present with glenohumeral pathology, such as instability and rotator cuff impingement syndrome.[40] Muscular weakness, inflexibility, and neuromuscular adaptations contribute to this loss of scapular control and scapular dyskinesis.[35,41,42] Rotator cuff strengthening is a necessary component of the rehabilitation of these glenohumeral pathologies.[4–8,37,38,43,44] The proximal-to-distal model suggests that effective and efficient rotator cuff strengthening depends on scapular control. In kinetic chain shoulder rehabilitation, intervention to normalize scapular movement precedes attempting to load the rotator cuff.

A primary role of the rotator cuff is to compress the humeral head in the glenoid and provide dynamic glenohumeral stability.[45–47] To do this effectively, the rotator cuff must operate from a stable scapular base and meet minimum strength requirements.[34,39] Exercising the rotator cuff without scapular stability could increase the risk of glenohumeral translation, create pain in rehabilitation, and increase the risk of further injury. Closed kinetic chain exercises promote cocontraction of rotator cuff musculature at submaximal levels.[48,49] Applying axial compression through the glenohumeral joint, as in closed-chain exercises, decreases glenohumeral translation at various levels of elevation.[50] Therefore, closed kinetic chain exercises have an important role in shoulder rehabilitation programs.[9,43,51] In these exercises, the clinician can determine and control the proximal load and scapular position by varying the athlete's stance and posture. Early in the rehabilitation process, closed kinetic chain exercises promote safe, functional cocontractions and can functionally strengthen the rotator cuff in preparation for open-chain exercises.[48–50]

PROXIMAL SEGMENT CONTROL

Based on proximal-to-distal sequencing, the arm ultimately depends on the segments proximal to it for movement. Full arm elevation requires full scapular retraction, which requires spinal extension, hip extension, and so on.[2,5,24] The large muscles of the hips and trunk thereby help position the thoracic spine to accommodate appropriate scapular motion. In many athletic activities, these muscles must provide stability for effective function of the shoulder girdle.[1] Normal motor patterns of forward arm elevation demonstrate ipsilateral activation of hip extensors before deltoid activation.[5] Kinetic chain rehabilitation attempts to take advantage of this by exaggerating the role of the hip extensors in an athlete with limited forward elevation. Forcing hip extension by including an ipsilateral step-up with a shoulder-flexion exercise seems to facilitate the shoulder flexion (Figure 1). Adding a PNF technique, the verbal queue to "get tall," encourages the thoracic extension that is necessary for complete arm elevation.[24,32] Additional resistance to the hip extension may stimulate an irradiation reflex to synergistic muscles and activate deficient shoulder flexors.[24,25]

Hip and trunk motion can facilitate shoulder motion in other planes. Proximal-to-distal muscle activation in rotational patterns consistent with PNF can facilitate shoulder rotation.[23] These types of movement patterns promote sequential muscle activation and coordination of proximal segment movement that can be built upon as the shoulder rehabilitation progresses.[5,24] A basic exercise that illustrates this is the "shoulder dump." To attain right shoulder external rotation and scapular retraction, the athlete assumes a left-foot-forward stance and begins with the left hip flexed, trunk flexed and rotated to the left, and right

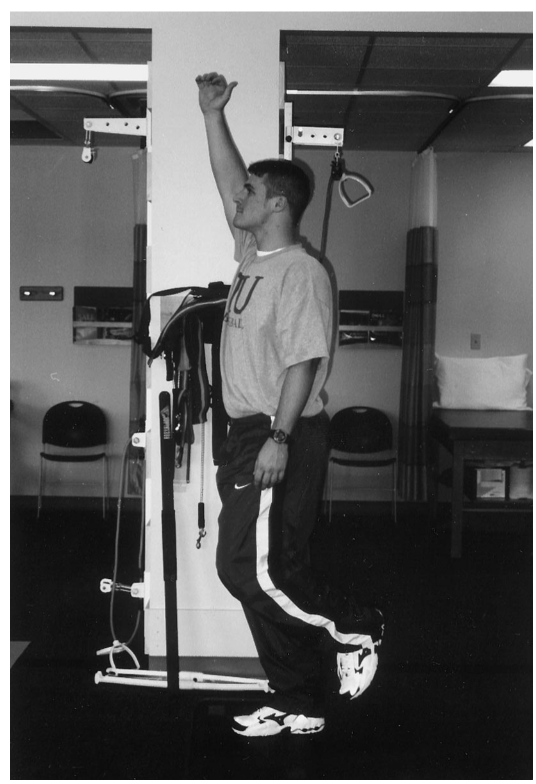

Figure 1. Shoulder flexion with ipsilateral anterior step-up.

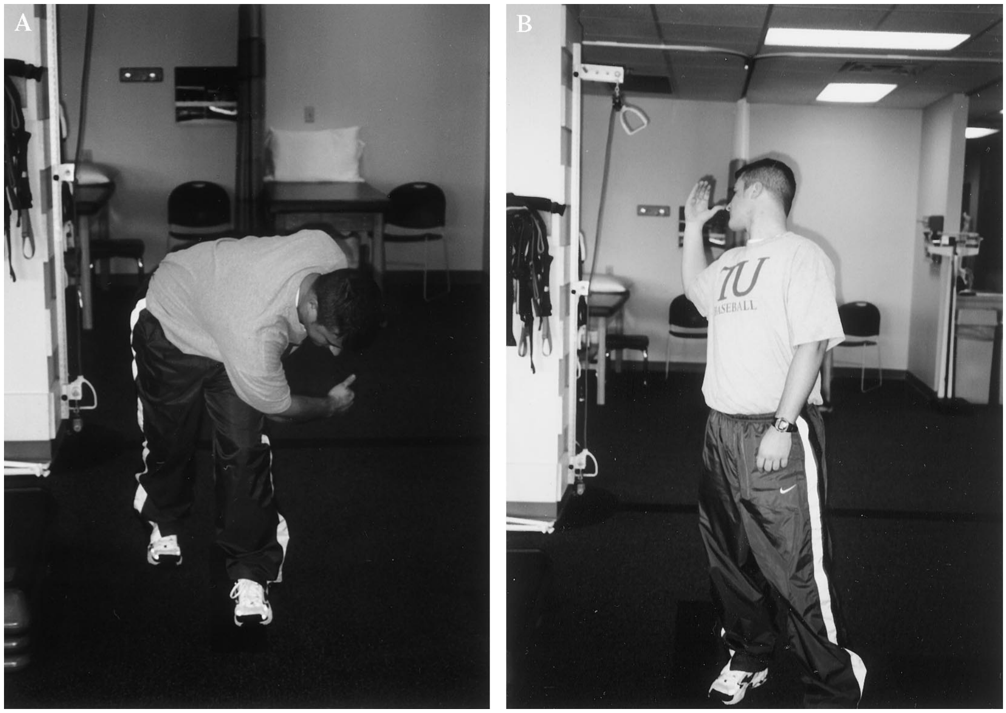

Figure 2. A, Starting position for the shoulder-dump exercise. Body weight is on the contralateral-side leg with trunk flexion and rotation. B, Finishing position. Body weight is on the ipsilateral-side leg with thoracic extension.

arm at knee level (Figure 2A). The athlete then shifts weight to the rear foot while extending and rotating the trunk to the right. Active retraction of the right scapula and external rotation of the right arm coincides with this weight shift and trunk extension (Figure 2B). The action simulates dumping a container backward. The degree of arm elevation, or the height at which the imaginary container is dumped, depends on the level of recovery and functional ability.

SCAPULAR FUNCTION AND CONTROL

Kinetic chain rehabilitation exercises use functional movement patterns to facilitate scapular motion and then to strengthen scapular musculature. Complementary movements by the legs and trunk, postural adjustments, and plane-of-movement modifications attempt to load scapular musculature and minimize muscular compensations. A common clinical scapular compensation involves the substitution of the upper trapezius, or exaggerated shoulder shrugging, during a scapular-retraction exercise. The kinetic chain approach deemphasizes the upper trapezius by concentrating on scapular depression with the retraction. Clinically, adjustments in the direction and amount of complementary trunk motion seem to minimize or eliminate muscular compensations so the scapula remains congruent with the thorax. One technique is to increase trunk rotation and thoracic extension with scapular retraction. Other feedback methods such as verbal queuing to "pull down," manually tapping on the lower trapezius, or applying manual resistance along the medial border of the scapula may assist active scapular depression and retraction.[24]

The first goal in obtaining scapular control and function is scapular retraction. One technique to aid in the reeducation of this movement is a modification of the previously described shoulder-dump exercise. By removing the arm movement, this becomes a trunk-facilitated scapular exercise. Complementary trunk motion, rather than isolated arm movements, helps establish the scapular retraction. The arm can remain in a sling during this exercise. The starting position is one of gravity-assisted scapular protraction (Figure 3A). Scapular retraction accompanies active spinal extension and ipsilateral rotation (Figure 3B). As scapular motion and control improve, reducing trunk motion, increasing arm elevation, or adding extrinsic loads increases scapular muscular demand.[52]

In addition to the modified shoulder dump, other scapular exercises include sternal lifts (Figure 4), tubing "fencing," (Figures 5A and 5B), and dumbbell or tubing punch and pull. Sternal lifts involve reciprocal thoracic flexion-extension with the emphasis on thoracic extension and scapular retraction. The athlete should feel as though he or she is pushing the sternum up and out but avoid lumbar hyperextension (Figure 4). If the athlete has difficulty pulling the scapula inferiorly and medially, the trunk and hip flexion in the reciprocal movement should increase.

Tubing fencing is a frontal-plane scapular-retraction exercise. In the starting position, the athlete reaches for the tubing with the involved arm in a lateral lunge stance (Figure 5A). The angle of the tubing should be horizontal or angled downward, to encourage scapular depression. From the reaching and lunging position, the athlete pushes off the leg on the involved side and pulls the arm into adduction. In the finished position, the elbow of the involved arm is against the ipsilateral hip, the shoulder is in approximately 90° of external rotation, and the body weight is on the leg of the uninvolved side (Figure 5B). The movement is similar to a lunge and parry in the sport of fencing. The athlete should focus on thoracic extension in the concentric phase of the exercise and on pulling the scapula medially without shrugging.

Punches with dumbbells are a protraction exercise that loads the serratus anterior concentrically and the posterior

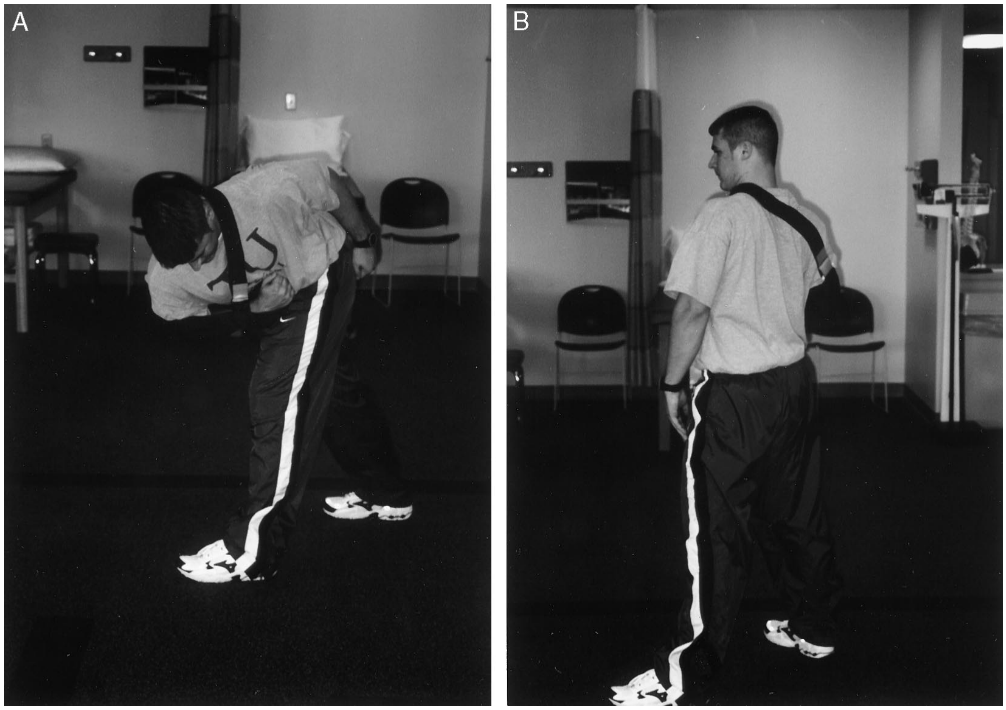

Figure 3. A, Starting, and B, Finishing position for modified shoulder-dump exercise with a sling.

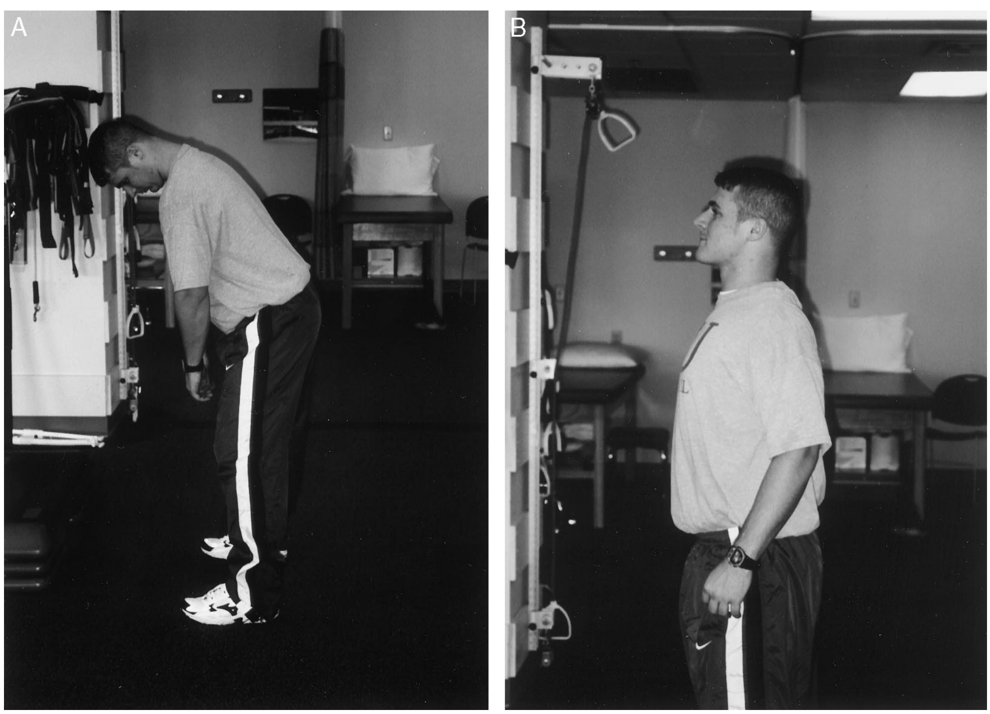

Figure 4. A, Sternal-lift starting position with head and trunk flexed forward. B, Finishing position emphasizing thoracic extension.

shoulder musculature eccentrically. A complementary stride accompanies the punches, and repetitions should be rhythmic to incorporate the proximal-to-distal activation and promote reciprocal scapular motion. For example, a contralateral forward stride accompanies a forward punch, and an ipsilateral lateral stride accompanies a lateral punch (Figure 6). The height and direction of the punch vary the rotator cuff load. By punching to knee level, the punch is gravity aided and reduces the load. Horizontal punches place the greatest load on the rotator cuff, extending the resistance the greatest distance from the shoulder joint.

CLOSED KINETIC CHAIN AND AXIALLY LOADED EXERCISES

In kinetic chain shoulder rehabilitation, closed kinetic chain exercises are exercises in which the hand is relatively fixed.[44] An example of this is the scapular-clock exercise, in which

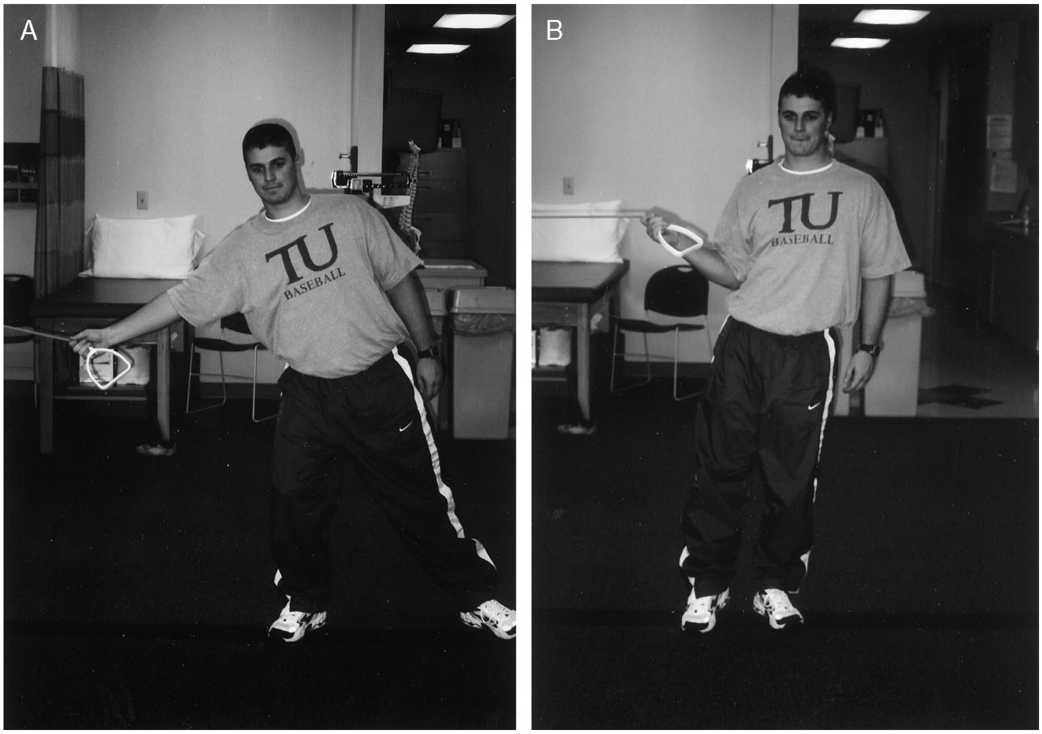

Figure 5. A, Tubing fencing exercise starting position with body weight on the ipsilateral leg. B, Finishing position. Elbow is at the hip; thoracic extension and scapular retraction are encouraged.

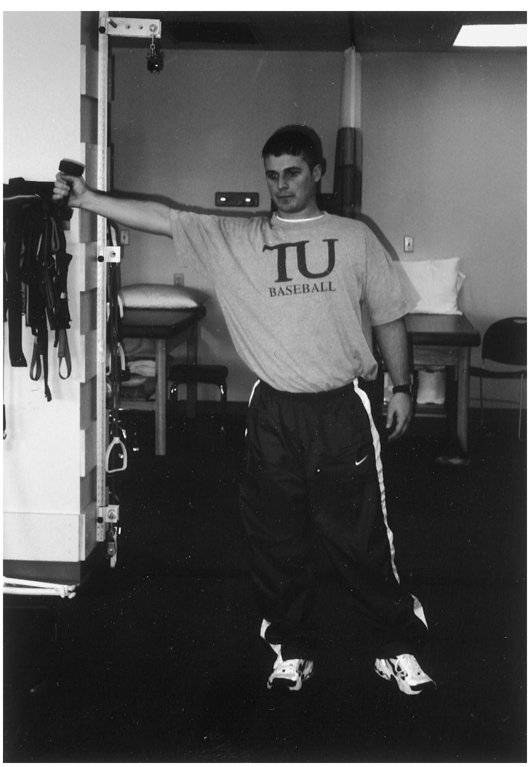

Figure 6. Lateral stride of ipsilateral leg with a lateral punch at shoulder height.

the athlete performs scapular elevation, depression, protraction, and retraction with the hand fixed on a stable surface at a safe degree of elevation. Additional closed kinetic chain exercises include weight shifts from hand to hand, stabilization on uneven surfaces, and modified push-ups.[8,53] Proper posture and proximal stability are important for these exercises. The posture should be "athletic," with feet shoulder-width apart, weight evenly distributed, slight hip and knee flexion, back straight, and head up. By assuming an athletic stance, the athlete can load the hips and trunk during these static exercises to promote proximal-to-distal activation patterns (Figure 7). Closed kinetic chain exercises should stimulate appropriate cocontractions of the shoulder girdle musculature at safe, pain-free positions within the arc of motion.

Kinetic chain shoulder rehabilitation includes light, axially loaded, active-motion exercises to promote active range of motion and as a transition to open-chain exercises. Decreasing the weight of the arm, as in upper extremity aquatherapy, diminishes the activation of the rotator cuff musculature.[54] Supporting the arm on a surface and lightly compressing through the glenohumeral joint may effectively diminish the weight of the arm as it moves through a range of motion on dry land. This compression and unloading may decrease the demand on weakened rotator cuff musculature during arm motion.

Axially loaded exercises allow the distal segment, usually the hand, to move while the athlete maintains an axial load through the glenohumeral joint. Because the distal segment moves deliberately, these are not strictly closed kinetic chain exercises.[44] Axially loaded exercises can incorporate the entire kinetic chain and may unload the weak shoulder girdle muscles by effectively reducing the intrinsic weight of the arm. This leads to increased pain-free shoulder active range of motion and minimized compensation patterns. Exercises such as table slides, ball rolling, and wall slides (Figure 8) are axially loaded shoulder exercises. The proximal legs and trunk can initiate these exercises, and the sliding hand can follow a flexion, abduction, diagonal, or curvilinear path, depending on the exercise goal.

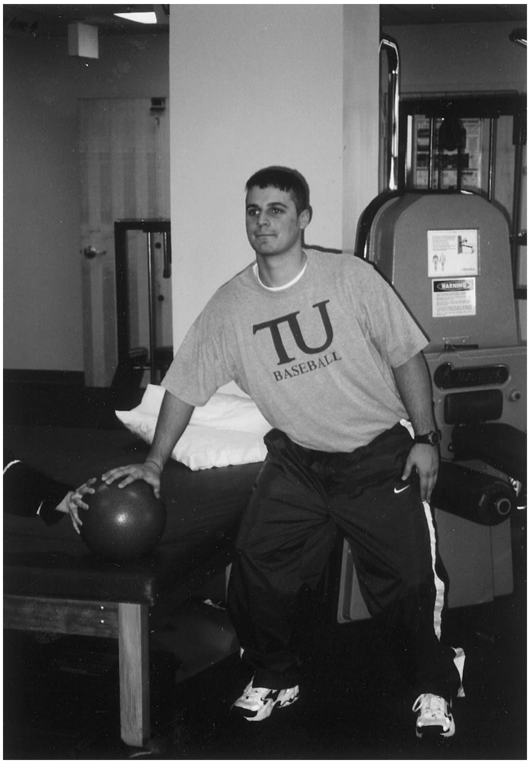

Figure 7. Athletic stance during ball-stabilization exercise.

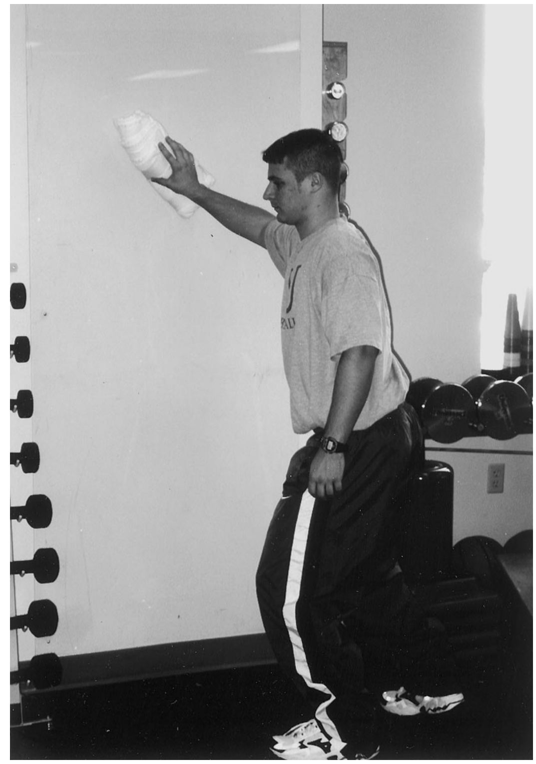

Figure 8. Axially loaded wall-slide exercise. Motion at the hips and trunk complements the sliding pattern of the hand.

PROGRESSION GUIDELINES FOR KINETIC CHAIN SHOULDER REHABILITATION

Safety and appropriate progression are major concerns in any rehabilitation program. A method exists to address these concerns in closed kinetic chain functional rehabilitation programs for the lower extremity.[55] Many of those principles are applicable to this upper extremity approach. The clinician needs to monitor exercise volume to avoid overloading the involved tissue when integrating multiple segments. When scapular exercises include arm elevation, rotator cuff activation will increase. An exercise program may be limited to 5 or 6 integrated exercises to avoid loads that weaken tissue.

It is important to continually monitor scapulothoracic rhythm, since this can be an early indicator of a compensation pattern. Reevaluation of the complete movement is necessary to accurately discern local fatigue from a proximal deficiency as the cause for the compensation. A common proximal deficiency that limits the proper performance of the shoulder dump is ipsilateral hip extensor or abductor weakness. Failure to achieve solid hip extension or allowing the hip to fall into adduction is a sign that hip weakness may be limiting the athlete's ability to perform the exercise. Including an ipsilateral-posterolateral stride in the exercise often allows the athlete to perform this shoulder movement without compensation. The stride may bring a normally subconscious hip muscle-activation pattern to a conscious level, or the hip may require independent strengthening to adequately contribute to the shoulder function. A goal of kinetic chain rehabilitation exercises is to perform movement patterns without compensations. Altering the dominant plane of motion, posture, resistance, or tactile or verbal feedback can achieve this goal. The exercises must then progress to the normal or appropriate movement pattern without exaggerated feedback or proximal facilitation. Progressively removing this feedback while the athlete maintains appropriate distal movement may allow the athlete to develop an internal feedback system. The athlete learns to maintain the appropriate shoulder motion as the feedback varies and facilitating motion is reduced to normal levels. The exercises, therefore, progress via this reduction in facilitation.

The initial emphasis of this rehabilitation approach is quality of movement in integrated movement patterns. The movements progress from the proximal segments to the distal segments of the kinetic chain. To progressively load the distal segments, the exercises advance from static closed kinetic chain to dynamic axially loaded to open kinetic chain. Progressions include reducing feedback, adding resistance, changing the stabilizing surface, and altering the movement pattern as the athlete gains rotator cuff strength and scapular control. Decreasing an axial load moves the exercises toward open kinetic chain, effectively increasing the intrinsic resistance to the rotator cuff by requiring it to control more of the arm's weight.[24] An example of this progression toward shoulder elevation might be standing upper extremity weight shifts, scapular clock, rhythmic ball stabilization, wall slides, and dumbbell punches. This distally focused progression would occur concurrently with a proximal scapular progression that begins with sternal lifts (Figure 4) and the modified shoulder dump (Figure 3).

The exercises become more sport specific as scapular control, active range of motion, and shoulder strength approach normal. A goal of these exercises is to fully integrate the strengthening of the scapular, rotator cuff, and trunk musculature with sport-specific movement patterns. These exercises are more traditional but continue to involve the kinetic chain, scapular control, and glenohumeral motion. Examples include standing overhead dumbbell presses in all planes and slow and controlled simulated sport activities. Overhead presses with dumbbells allow the shifting of body weight or striding to incorporate the proximal kinetic chain. Slow, controlled swinging or throwing movements, with correct mechanics, are difficult exercises that place a premium on kinetic chain stabilization during sport-specific movement patterns. Explosive plyometic activities, such as medicine-ball tossing, are the final progression. The movement patterns of the athlete's sport become the dominant movement patterns of these advanced exercises.

CONCLUSIONS

This is a nontraditional approach to the rehabilitation of the shoulder that concentrates on movement patterns. The kinetic chain approach addresses glenohumeral motion through scapular control and scapular control through trunk movement. It is consistent with the proximal-to-distal kinetic link model of biomechanics and applies current concepts of motor control and closed kinetic chain exercise.

The best illustration of functional kinetic chain rehabilitation is a spectrum, ranging from dysfunction to full function rather than a step-by-step outline.[56] An athlete's exercise program is a combination of the various types of exercises gradually progressing along the spectrum toward full function.

Several concepts are important to kinetic chain shoulder rehabilitation:

1. For shoulder rehabilitation to be truly functional, the approach to the upper extremity should follow a proximal-to-distal pathway along a kinetic chain.
2. Muscles around the shoulder function synergistically and should be integrated within a kinetic link system throughout rehabilitation.
3. Scapular control and coordinated rotator cuff activation are vital to successful shoulder rehabilitation and safe shoulder function.
4. Graded closed kinetic chain exercises for the upper extremity belong in the initial phase of shoulder rehabilitation.

This article provides the theoretical background to support the concepts of kinetic chain rehabilitation and some basic techniques. Clinically, many patients who have failed with traditional shoulder programs have benefited from this approach. We hope this information benefits other, similar patients and inspires scientific investigation into the currently unsupported concepts and clinical efficacy of this approach.

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REFERENCES

1. Kibler WB. Evaluation of sports demands as a diagnostic tool in shoulder disorders. In: Matsen FA, Fu FH, Hawkins RJ, eds. *The Shoulder: A Balance of Mobility and Stability*. Rosemont IL: American Academy of Orthopaedic Surgeons; 1993:379–395.
2. Putnam CA. Sequential motions of body segments in striking and throwing skills: description and explanations. *J Biomech*. 1993;26:125–135.
3. Feltner ME, Dapena J. Three-dimensional interactions in a two-segment kinetic chain, part I: general model. *Int J Sport Biomech*. 1989;5:403–419.
4. Cordo PJ, Nashner LM. Properties of postural adjustments associated with rapid arm movements. *J Neurophysiol*. 1982;47:287–308.
5. Zattara M, Bouisset S. Posturo-kinetic organisation during the early phase of voluntary upper limb movement, 1: normal subjects. *J Neurol Neurosurg Psychiatry*. 1988;51:956–965.
6. Brewster C, Schwab DR. Rehabilitation of the shoulder following rotator cuff injury or surgery. *J Orthop Sports Phys Ther*. 1993;18:422–426.
7. Wilk KE, Harrelson GL, Arrigo C, Chmielewski T. Shoulder rehabilitation. In: Andrews JR, Harrelson GL, Wilk KE, eds. *Physical Rehabilitation of the Injured Athlete*. 2nd ed. Philadelphia, PA: WB Saunders; 1998:478–553.
8. Kibler WB. Shoulder rehabilitation: principles and practice. *Med Sci Sports Exerc*. 1998;30:S40–S50.
9. Lephart SM, Henry TJ. The physiological basis for open and closed kinetic chain rehabilitation for the upper extremity. *J Sport Rehabil*. 1996;5:71–87.
10. Lephart SM, Pincivero DM, Giraldo JL, Fu FH. The role of proprioception in the management and rehabilitation of athletic injuries. *Am J Sports Med*. 1997;25:130–137.
11. Paine RM, Voight M. The role of the scapula. *J Orthop Sports Phys Ther*. 1993;18:386–391.
12. Bunn JW. *Scientific Principles of Coaching*. Englewood Cliffs, NJ: Prentice-Hall; 1972.
13. Kreighbaum E, Barthels KM. Throwlike and pushlike movement patterns. In: *Biomechanics: A Qualitative Approach for Studying Human Movement*. 4th ed. Boston, MA: Allyn and Bacon; 1996:335–354.
14. Fleisig GS, Barrentine SW, Escamilla RF, Andrews JR. Biomechanics of overhand throwing with implications for injuries. *Sports Med*. 1996;21: 421–437.
15. Gordon J. Assumptions underlying physical therapy intervention: theoretical and historical perspectives. In: Carr JH, Shepherd RB, Gordon J, Gentile AM, Held JM, eds. *Movement Science: Foundations for Physical Therapy in Rehabilitation*. Rockville, MD: Aspen; 1997:1–30.
16. Polit A, Bizzi E. Characteristics of motor programs underlying arm movements in monkeys. *J Neurophysiol*. 1979;42:183–194.
17. Gelfand IM, Gurvinkel VS, Tsetlin ML, Shik ML. Some problems in the analysis of movements. In: Gelfand IM, Gurfinkel VS, Formin SV, Tsetlin ML, eds. *Models of the Structural-Functional Organization of Certain, Biological Systems*. Cambridge, MA: The Massachusetts Institute of Technology Press; 1971:329–345.
18. Shumway-Cook A, Woollacott MH. Theories of motor control. In: *Motor Control: Theory and Practical Applications*. Baltimore, MD: Williams & Wilkins; 1995:3–118.
19. Bouisset S, Zattara M. A sequence of postural movements precedes voluntary movement. *Neurosci Lett*. 1981;22:263–270.
20. Bullock-Saxton JE. Local sensation changes and altered hip muscle function following severe ankle sprain. *Phys Ther*. 1994;74:17–31.
21. Hodges PW, Richardson CA. Feedforward contraction of transversus abdominus is not influenced by the direction of arm movement. *Exp Brain Res*. 1997;114:362–370.
22. Voss DE, Knott M, Kabat H. The application of neuromuscular facilitation in the treatment of shoulder disabilities. *Phys Ther Rev*. 1953;33:536–541.
23. Voss DE. Proprioceptive neuromuscular facilitation. *Am J Phys Med*. 1967;46:838–898.
24. Knott M, Voss DE. *Proprioceptive Neuromuscular Facilitation Patterns and Techniques*. 2nd ed. Philadelphia, PA: Harper Row; 1968:3–225.
25. Sherrington CS. *The Integrative Action of the Nervous System*. New Haven, CT: Yale University Press; 1906:1–411.
26. Kabat H. The role of central facilitation in restoration of motor function in paralysis. *Arch Phys Med*. 1952;33:521–533.
27. Culham E, Peat M. Functional anatomy of the shoulder complex. *J Orthop Sports Phys Ther*. 1993;18:342–350.
28. Perry J. Muscle control of the shoulder. In: Rowe CR, ed. *The Shoulder*. New York, NY: Churchill Livingstone; 1988:17–34.
29. Inman VT, Saunders M, Abbott LC. Observations of the function of the shoulder joint. *J Bone Joint Surg Am*. 1944;26:1–31.
30. Perry J. Anatomy and biomechanics of the shoulder in throwing, swimming, gymnastics, and tennis. *Clin Sports Med*. 1983;2:247–270.
31. Van der Helm FC. A finite element musculoskeletal model of the shoulder mechanism. *J Biomech*. 1994;27:551–569.

32. Kapandji IA. *The Physiology of the Joints*. 5th ed. New York, NY: Churchill Livingstone; 1982:2–283.
33. Ludewig PM, Cook TM, Nawoczenski DA. Three-dimensional scapular orientation and muscle activity at selected positions of humeral elevation. *J Orthop Sports Phys Ther*. 1996;24:57–65.
34. Happee R, Van der Helm FC. The control of shoulder muscles during goal directed movements: an inverse dynamic analysis. *J Biomech*. 1995;28: 1179–1191.
35. Kendall FP, McCreary EK, Provance PG. Upper extremity and shoulder girdle strength test. In: Butler JP, ed. *Muscle Testing and Function*. Baltimore, MD: Williams & Wilkins; 1993:235–298.
36. Travell JG, Simons DG. *Myofascial Pain and Dysfunction: The Trigger Point Manual*. Baltimore, MD: Williams & Wilkins; 1983:1–684.
37. Kibler WB, McQueen C, Uhl TL. Fitness evaluations and fitness findings in competitive junior tennis players. *Clin Sports Med*. 1988;7:403–416.
38. Brown LP, Niehues SL, Harrah A, Yavorsky P, Hirshman HP. Upper extremity range of motion and isokinetic strength of the internal and external shoulder rotators in major league baseball players. *Am J Sports Med*. 1988;16:577–585.
39. Kibler WB. The role of the scapula in athletic shoulder function. *Am J Sports Med*. 1998;26:325–337.
40. Warner JJP, Micheli LJ, Arslanian LE, Kennedy J, Kennedy R. Scapulothoracic motion in normal shoulders and shoulders with glenohumeral instability and impingement syndrome. *Clin Orthop*. 1992;285:191–199.
41. Lukasiewicz AC, McClure P, Michener L, Pratt N, Sennett B. Comparison of 3-dimensional scapular position and orientation between subjects with and without shoulder impingement. *J Orthop Sports Phys Ther*. 1999;29: 574–586.
42. Kasman GS, Cram JR, Wolf SL. *Clinical Applications in Surface Electromyography: Chronic Musculoskeletal Pain*. Gaithersburg, MD: Aspen; 1998:1–42.
43. Borsa PA, Livingston B, Kocher MS, Lephart SP. Functional assessment and rehabilitation of shoulder proprioception for glenohumeral instability. *J Sport Rehabil*. 1994;3:84–104.
44. Steindler A. *Kinesiology of the Human Body*. Springfield, MA: Charles C Thomas; 1955.
45. Saha AK. Dynamic stability of the glenohumeral joint. *Acta Orthop Scand*. 1971;42:491–505.
46. Itoi E, Newman SR, Kuechle DK, Morrey BF, An KN. Dynamic anterior stabilisers of the shoulder with the arm in abduction. *J Bone Joint Surg Br*. 1994;76:834–836.
47. Cain PR, Mutschler TA, Fu FH, Lee SK. Anterior stability of the glenohumeral joint: a dynamic model. *Am J Sports Med*. 1987;15:144–148.
48. Dillman CJ, Murray TA, Hintermeister RA. Biomechanical differences of open and closed chain exercises with respect to the shoulder. *J Sport Rehabil*. 1994;3:228–238.
49. Kibler WB, Livingston B, Bruce R. Current concepts in shoulder rehabilitation. *Adv Oper Orthop*. 1995;3:249–299.
50. Warner JJP, Bowen MK, Deng X, Torzilli PA, Warren RF. Effect of joint compression on inferior stability of the glenohumeral joint. *J Shoulder Elbow Surg*. 1999;8:31–36.
51. Wilk KE, Arrigo A, Andrews JR. Closed and open kinetic chain exercise for the upper extremity. *J Sport Rehabil*. 1996;5:88–102.
52. Moseley JB, Jobe FW, Pink M, Perry J, Tibone J. EMG analysis of the scapular muscles during a shoulder rehabilitation program. *Am J Sports Med*. 1992;20:128–134.
53. Wilk KE, Arrigo C. Current concepts in the rehabilitation of the athletic shoulder. *J Orthop Sports Phys Ther*. 1993;18:365–378.
54. Fujisawa M, Suenaga N, Minami A. Electromyographic study during isometric exercise of the shoulder in head-out water immersion. *J Shoulder Elbow Surg*. 1998;7:491–494.
55. Pitney WA, Bunton EE. The Integrated Dynamic Exercise Advancement System technique for progressing functional closed kinetic chain rehabilitation programs. *J Athl Train*. 1994;29:297–300.
56. Gray GW. *Chain Reaction Festival Course Manual*. Chicago, IL: Wynn Marketing; 1997.