

FUNCTIONAL REHABILITATION FOR THE UPPER AND LOWER EXTREMITY

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Functional rehabilitation is an integral part of any rehabilitation program. The functional rehabilitation phase incorporates not only the traditional elements of physical therapy, such as strength and flexibility, but also activities to enhance agility, proprioception, and neuromuscular control. Agility and kinesthetic training are incorporated to restore neuromuscular mechanisms responsible for joint kinematics, enabling the individual to return to preinjury levels of activity while also reducing the risk of reinjury.^{22,31} Traditional rehabilitation programs emphasize returning to activities of daily living but do not always prepare the individual for activities that may involve running, cutting, or turning. Many individuals participate in high levels of activity, such as sports, that necessitate the restoration of these neuromuscular mechanisms promoting functional stability when extreme loads are placed on previously injured structures. Therefore, a return to preinjury level of activity is the objective of the functional rehabilitation program.

It has been well documented that restoring deficits in strength, flexibility, and power may not be sufficient to return an individual to their preinjury level of sport activity.^{22,26,27} Each sport uniquely involves imparting different demands on the neuromuscular and physiologic system of the athlete. Therefore, the principle of specificity must be incorporated into the functional rehabilitation program. The speci-

ficity of the training principle involves matching the neuromuscular and physiologic demands of rehabilitation with those that the athlete will be returning to. Specificity during functional rehabilitation restores reflex muscle activity and conditioning characteristics required by the activities the individual will perform.

OBJECTIVES OF FUNCTIONAL REHABILITATION

The objective of functional rehabilitation is to return the athlete to his or her preinjury activity level while minimizing the risk of reinjury. Functional rehabilitation activities are designed to restore both functional stability, using dynamic (muscular) mechanisms, and sport specific skills. To properly meet the specific needs of the individual athlete and the respective injury, the clinician needs to design each rehabilitation program accordingly. The specific elements incorporated into the functional rehabilitation program are determined by both the existing pathology and the desired activity the athlete will return to.²²

The first objective that should be addressed in functional rehabilitation is the restoration of functional stability. Functional stability is the ability to control the translation of the particular joint during dynamic functional activities.

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Functional stability refers to the integration of both primary and secondary joint stabilizers to permit normal joint kinematics during dynamic activities.⁵² It is imperative that functional stability be restored before performing activities such as acceleration, deceleration, twisting, and cutting maneuvers typical in sports. Re-establishment of functional stability is dependent upon the pathogenesis of the injury and whether surgical or nonsurgical management of the condition is necessary. An athlete who elects nonsurgical management of an injury must re-establish stability by dynamic muscular compensation, although an athlete who elects for surgical management has stability restored through the surgery.⁴³ Injury to the anterior cruciate ligament is a very common example of the different options an athlete may be faced with. Nonsurgical management would involve developing muscular compensation to control the anterior tibial translation that was inherently provided by the anterior cruciate ligament (ACL). Conversely, surgery restores the inherent stability of the knee, and rehabilitation must address restoration of those characteristics compromised as a result of the surgical procedure. Although the initial stages of rehabilitation may differ in their immediate objectives, the final stages of functional rehabilitation will be similar regardless of these management options because the ultimate goal is to allow the athlete to return to preinjury levels of activity.²²

Strength, flexibility, and range of motion are necessary to restore functional stability along with reflex stabilization and coordinated motor patterns. The functional phase must concentrate on restoring complex neuromotor patterns that are specific to the desired sport the athlete will return to following rehabilitation.

The second objective of functional rehabilitation and training is to restore sport-specific skills and movement patterns. Agility and sport-specific activities are included to refine the physiologic and psychologic parameters necessary to return to preinjury levels of functional performance.

The final phase of functional rehabilitation involves assessing the athlete's readiness to return to his or her desired sport activity. Often an athlete returns prematurely to participation, and this leads to reinjury. Traditionally the clinician has used clinical assessments to determine the athlete's readiness to return to his or her functional activity. In the past, this has led to a premature return to participation resulting in a recurrent injury.^{10,22,33,35,46,51} Recently, tests that actually reproduce functional activities

and place functional-type loads on the injured structures have been developed to assess dynamic capability and functional stability. These tests can be objectively measured to assess the athlete's functional level. Functional testing provides the clinician with an objective assessment of the athlete's readiness to return to their specific sport activity.

IMPLEMENTATION OF FUNCTIONAL REHABILITATION

The functional phase of rehabilitation must be preceded by a progression of traditional physical therapy phases that ensure normal healing and restoration of joint motion, muscular strength, and muscular endurance. The restoration of these characteristics must precede the functional activities that are sport specific and require such activities as running and cutting or throwing in overhead injuries.^{22,31} Most of the therapeutic activities performed before the beginning of the functional phase are dictated by specific injury or surgical procedures and may differ among clinicians. During the functional phases of rehabilitation, it is important that the athlete continues specific strengthening, range-of-motion, and proprioceptive exercises that were initiated during earlier phases of rehabilitation.

Each surgeon may differ relative to the time when the functional phase of the rehabilitation program should be implemented. For the purposes of this discussion, the authors suggest that functional rehabilitation begin once the athlete has near full, pain-free range of motion that is sufficient for participation in athletic activity. In the knee, it is suggested that the athlete have 8 to 118 degrees of knee joint motion and can demonstrate a normal walking gait, can ascend and descend stairs, and can demonstrate no gait deviation when running.^{22,31} Criteria for the shoulder are less objective and usually include near pain-free full range of motion and sufficient strength to perform the given activity.

NEUROMUSCULAR AND PROPRIOCEPTION REHABILITATION

The demands placed on the neuromuscular mechanism during sport activities include having sufficient strength and endurance to perform the activity and providing adequate joint stabilization to compensate for deficiencies

following an injury. Muscular strengthening and endurance activities are initiated during the prefunctional phases of the rehabilitation program and are often near completion when the functional program begins. The functional component of the rehabilitation program begins with simple activities, such as running, and progresses to highly complex maneuvers requiring refined neuromuscular mechanisms including proprioceptive or kinesthetic awareness that provides joint stabilization. The progression from simple activities to more refined activities cannot take place until proprioceptive deficits from the injury are minimized.²²

Proprioception is considered a specialized variation of the sensory modality of touch and encompasses the sensations of joint movement (kinesthesia) and joint position (joint position sense). Conscious proprioception is essential for proper joint function in sports, activities of daily living, and occupational tasks. Unconscious proprioception modulates muscle function and initiates reflex stabilization. Articular structures in both the upper and lower extremities have a significant sensory function that plays a role in dynamic joint stability, acute and chronic injury, pathologic wearing, and rehabilitation training.²⁵

Proprioception plays a protective role in acute injury through reflex muscle splinting. The protective reflex arc initiated by mechanoreceptors and muscle spindle receptors occurs much more rapidly than the reflex arc initiated by nociceptors (70–100 m/sec vs. 1 m/sec). Thus, proprioception may play a more significant role than pain sensation in preventing injury in the acute setting. Proprioceptive deficits, however, probably play more of a role in the cause of chronic injuries and reinjury. Initial injury results in partial deafferentation and sensory deficits that can predispose to further injury.^{19,22} Proprioceptive deficits may also contribute to the cause of degenerative joint disease through pathologic wearing of a joint with poor sensation. It is unclear whether the proprioceptive deficits that accompany degenerative joint disease are a result of the underlying pathologic process or contribute to the cause of the pathologic process.

Functionally, the authors' laboratory and others assess kinesthesia by measuring threshold to detection of passive motion (TTDPM) and joint position sense is assessed by measuring reproduction of passive positioning (RPP).^{2,3,4,22,25} Using these measures in the knee, investigators have found proprioceptive deficits with aging,⁴² arthrosis,⁴ and ACL disruption,³ while we have identified deficits in patients following ACL reconstruction²⁵ and in

patients with unilateral, traumatic, recurrent, anterior glenohumeral instability.⁶ These processes damage articular structures containing mechanoreceptors resulting in partial deafferentation with resultant proprioceptive deficits. Proprioceptive enhancement was found to occur in ballet dancers,² and the authors found enhanced proprioception in gymnasts²³ and while using neoprene compression sleeves,²⁵ suggesting that training and bracing have proprioceptive benefits.

Methods to improve proprioception after injury or surgery could improve function and decrease the risk of reinjury. Afferent input is altered after joint injury and may remain altered after joint reconstruction. Proprioceptive rehabilitation, however, may allow the patient to retrain altered afferent pathways resulting in enhanced sensation of joint movement. Therefore, proprioceptive training has become an integral aspect of functional rehabilitation.²²

Proprioception training begins early in the rehabilitation program with such simple tasks as balance training and joint repositioning and becomes increasingly more difficult as the patient progresses. Once the athlete has reached the functional stage of rehabilitation the objectives of proprioception training are to refine joint position awareness which initiates muscle reflex stabilization to prevent reinjury. Additionally, proprioceptive acuity plays an important role in performance of those athletes requiring precision in their movement patterns.

Proprioception exercises enhance the muscles ability to provide joint stability and refine movement patterns. Therefore, proprioception activities are very functional and are related to both injury reduction and performance enhancement. Because the proprioceptive mechanism comprises both conscious and unconscious pathways, these exercises need to include consciously mediated pattern sequences and sudden alterations of joint positions that initiate reflex muscle contraction. Proprioception training exercises that permit balancing on an unstable platform while the athlete performs a sport specific skill, integrate both these neural pathways and maximally stimulate kinesthetic awareness. Therefore, proprioception exercise progression should begin with activities such as balance training and progress to highly complex sport specific activities.²²

The primary considerations relative to proprioceptive rehabilitation are reflex muscle stabilization and conscious appreciation of joint motion and position. An understanding of the central nervous system's (CNS) influence on

motor activities is necessary to develop a proper rehabilitation program. The CNS motor control functions at three distinct levels.

1. At the spinal level, reflexes subserve movement patterns that are received from higher levels of the nervous system. This provides for reflex splinting during conditions of stress about the joint. The muscle spindles play a major role in the control of muscular movement by adjusting activity in the lower motor neurons. Partial deafferentation of joint afferent receptors has also been suggested to alter the musculature's ability to provide cocontraction joint stabilization by antagonistic and synergistic muscles, thus resulting in the potential for reinjury.^{6,11,24}
2. The brain stem is the second level of motor control. Joint afference is relayed to maintain posture and balance of the body. The input to the brain stem relative to body position emanates in the joint proprioceptors, the vestibular centers in the ears, and the eyes.⁶
3. The third aspect of motor control involves the highest level of CNS function and is mediated by cognitive awareness of body position and movement. These higher centers initiate and program motor commands for voluntary movements. Movements that are repeated can be stored as central commands and can be performed without continuous reference to consciousness.⁶

Each of these three levels of motor control must be addressed specifically during neuromuscular and proprioceptive rehabilitation. At the spinal level, activities that encourage reflex joint stabilization should be included.⁶ These activities would include sudden alterations in joint positioning that require reflex muscular stabilization. These types of exercises stimulate both articular and muscular mechanoreceptors for reflex stabilization. These reflex stabilization exercises provide a mechanism for developing dynamic joint stability.

Cognitive appreciation of joint position also needs to be included in proprioceptive training. These types of activities are initiated at the cognitive level and include programming motor commands for voluntary movement. The repetition of movements will maximally stimulate the conversion of conscious programming to unconscious programming. This information is then stored as central com-

mands and can be performed without continuous reference to consciousness.

LOWER EXTREMITY FUNCTIONAL REHABILITATION

In the lower extremity, a good marker for the onset of the functional rehabilitation phase includes when the athlete can walk normally, ascend and descend stairs, and can show no gait deviation when running.²² These criteria all involve closed kinematic chain assessments and are specific to returning to most functional activities. Closed kinetic chain activities are also highly recommended as the integral component of functional rehabilitation. Because both ends of the kinematic chain are fixed in closed chain exercise, the activities assimilate joint loading forces and kinematics that occur functionally. Closed kinetic chain exercises for the lower extremity permit the entire linkage system of the hip, knee, and ankle to be exercised together while reproducing the axial orientation of walking and running. This orientation permits muscular firing patterns necessary for both joint stabilization and ambulation and necessitates muscle activation in the synchronized manner assimilating functional activities.³⁷ This integration of agonist, antagonist, and synergist muscle activity necessary for both stabilization and ambulation is the fundamental rationale for using closed-chain exercise during functional rehabilitation.

Proponents of closed kinetic chain exercises for the lower extremity have also advocated their use to reduce loads on the patellofemoral and tibiofemoral joints. Many studies have documented reduced shearing forces in the knee and decreased tibial translation, especially on the ACL and PCL, with closed-chain exercise as opposed to open-chain exercise.^{8,29,48} Tibial shear forces in the knee have been described using a biomechanical model by Palmitier et al.³⁷ The model describes forces as shearing and compressive. During closed-chain exercise, the reduction in tibial translation is suggested to be the result of an axial load being applied to the tibia. This axial loading produces increased compressive forces resulting in decreased shearing force, therefore reducing tibial translation. During open-chain knee extension, the compressive component is perpendicular to the tibial plateaus, and the shear component is parallel to the joint surface. This shear component causes anterior and posterior tibial translation.

Open- and closed-chain activities also produce differing forces within the patellofemoral

joint. During open-chain knee extension, the patellofemoral joint reaction forces are very high and concentrated on a very small contact area. This results in large contact stresses per unit of area. For closed-chain flexion, the patellofemoral joint reaction forces are also high but they are concentrated on a larger contact area, resulting in less contact stress per unit of area.¹⁵ Therefore, closed-chain exercise decreases the incidence of secondary patellofemoral joint pathology.

Closed kinetic-chain exercises are very specific to the functional demands placed on the lower extremity during sport activities. During these activities, the body moves over the foot resulting in simultaneous movement of all joints of the lower extremity. Coordinated muscular activity including concentric and eccentric cocontraction of antagonistic muscle groups are required to control all segments of the kinetic chain during closed-chain activities.

Although closed-chain activities seem to be the most appropriate method of functionally training the lower extremity, open kinetic-chain exercise can be used effectively when coupled with specific closed-chain exercise. Open-chain exercise results in isolated movement at a given joint. These exercises are effective when isolated strengthening for specific muscle groups is desired (Fig. 1). Once these areas of isolated weakness are eliminated, closed-chain exercises can be implemented to develop the coordinated muscle activity required for joint stabilization and functional activities.

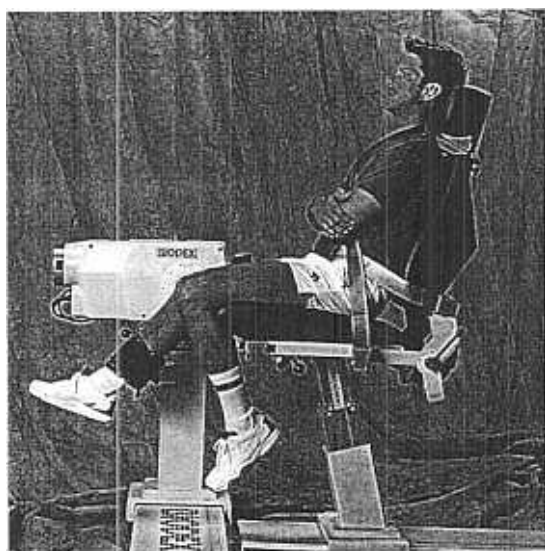


Figure 1. Lower extremity isokinetic Open Kinematic Chain Exercise (Biomed Medical Systems, Inc., Shirely, NY).

The combination of open and closed kinetic-chain exercises can be the most effective approach in the lower extremity for returning the athlete to his or her activity. The use of both open and closed kinematic-chain activities should be used to mediate the development of functional stability. The concept of specificity should also be considered when designing both open- and closed-chain activities in promoting functional stability in the lower extremity.^{9,12,22}

UPPER EXTREMITY FUNCTIONAL REHABILITATION

As with the lower extremity, strength and flexibility are prerequisites to beginning the functional rehabilitation phase in the upper extremity. Unlike the lower extremity in which most of the emphasis is placed on closed kinetic-chain activities, upper extremity functional training involves both open and closed kinematic-chain activities. The specificity principle is especially important when designing an upper extremity rehabilitation because of the complexity of upper extremity function. In the lower extremity, most, if not all, activity takes place in a closed kinematic-chain position; however, this is not the case with the upper extremity. Most types of throwing motions or overhead activities occur in an open-chain position, while blocking in football or participating in gymnastics may be closed-chain activities.⁶ There is considerable controversy regarding the use of open versus closed kinematic-chain exercises in the upper extremity; the authors feel that both open and closed kinetic-chain activities need to be incorporated into the upper extremity functional program based on the outcome objectives of the individual.

Rather than isolating open- or closed-chain activities in the upper extremity, concentrating on functional positioning during exercise may be more appropriate. Ideally, an overhead-throwing athlete should be trained in the position of vulnerability to induce neural adaptations on this position. Conversely, a gymnast or football player should rehabilitate in the anatomical position that resulted in the pathoetiology of the injury or instability.⁶

The upper extremity involves a very delicate balance between mobility and stability.* The clinician must consider this balance when designing a functional rehabilitation program for

*References 5, 13, 14, 34, 36, 39, 40, 41, 47, 50.

the upper extremity. The importance of establishing a balance between the scapular stabilizers, rotator cuff, and noncontractile tissues is imperative. Rehabilitation activities before the functional phase must maximally recruit the muscles responsible for humeral and scapular rotation and stabilization. Another important aspect in the upper extremity functional rehabilitation is eccentric exercise. This needs to be emphasized in all phases of the rehabilitation process. Eccentric loading of the rotator cuff places high stress on the musculature and may reduce injury by permitting higher levels of dynamic stability. Restoring this balance involves not only muscular strengthening and flexibility, but also enhancing cognitive appreciation of the respective joint relative to position and motion, and to enhance muscular stabilization of the joint in the absence of structural restraints.⁶ These types of exercises provide a muscle strength and endurance base necessary for the more functional exercises initiated in the functional phases of the rehabilitation program.

Some basic principles have been developed by Litchfield et al²⁸ that can be used when developing an upper extremity functional rehabilitation program, especially with the overhead throwing athlete. The first principle is to rehabilitate the shoulder in functional planes of motion. Most exercises should be performed in or anterior to the scapular plane. This is generally a pain-free range. The second principle is to gain muscular control of the arm in the deceleration phase of throwing. Most overhead injuries occur during eccentric loading of the muscle, therefore it is imperative that functional rehabilitation strengthens the musculature eccentrically to provide effective control during deceleration. The third principle is to train the athlete in a manner that will reproduce forces that will occur during the overhead throwing motion.

THE LOWER EXTREMITY FUNCTIONAL REHABILITATION PROGRAM

The functional rehabilitation program for the lower extremity begins with forward running and progresses to more complex activities that require cutting, turning, acceleration and deceleration, and other highly agile maneuvers. The progression from forward running to cutting and turning is dictated by the refinement of kinesthetic acuity that permits dynamic joint stabilization when torsion and translatory forces are placed on the lower extremity. The authors have divided the lower extremity func-

tional rehabilitation program into four phases that provide for a clear understanding of the progression of activities that need to be incorporated²² (Table 1).

Phase I of the functional rehabilitation program consists of a jog or walk activity on flat and straight surfaces. This emphasizes the transition from strength acquired clinically into functional strength and the redevelopment of a kinesthetic gait.^{22,31} During phase I of the program, the proprioceptive exercises concentrate on balance and dynamic joint stabilization that will permit the athlete to progress to directional changes in the next phase of the rehabilitation program (Fig. 2). Ascending and descending stairs both forward and backward should be initiated during this phase to involve eccentric loading to the extremity. Aerobic conditioning should also be initiated during the later stages of this phase. It is usually very difficult to impart sufficient stress on the cardiovascular system for conditioning during running activities following injury or surgery to the lower extremity. An alternative form of conditioning should be used that provides the required aerobic stress. Suggested exercises include biking and swimming.²²

Phase II of lower extremity functional rehabilitation encourages turning and changing direction. Activities that will initiate turning and changing directions include running figure-of-eight, beginning with large circles and progressively running smaller circles with increasing speed as the athlete's confidence and ability permits. The figure-of-eight should be performed in both directions. The proprioceptive activities in phase II involve more dynamic movements and encourage changing directions rapidly, landing, and performing balancing maneuvers while involved in sports-specific activities. Plyometrics may also be initiated during this phase to begin development of explosive contractile strength and permit eccentric deceleration of knee joint extension.^{22,31} These plyometric activities should begin at a comfortable height and be progressively increase as tolerated. Lateral movements may also be initiated during this phase. Such activities can be performed on a slide board. These activities permit the development of balance while moving laterally and joint stabilization by cocontraction of the quadriceps and hamstring muscle groups. Aerobic conditioning should be continued during this phase.

Phase III of the functional program prepares the athlete for return to sport-specific activities. This phase must involve activities that reproduce the stress that will be placed upon the

Table 1. PHASES OF FUNCTIONAL REHABILITATION

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| Phase I | Upper body ergometry |
| Walk/Run Series | Swimming |
| Performed on flat/straight surfaces, progressing to continuous running | Phase III |
| Proprioception Training | Running |
| Two feet balancing on unstable platform, eyes open, multidirectional | Shuttle run |
| Two feet balancing on unstable platform, eyes closed, multidirectional | Cocontraction lateral slides |
| One foot balancing on unstable platform, eyes open, unidirectional | Proprioception/Agility Training (progress to normal speed) |
| One foot balancing on unstable platform, eyes closed, unidirectional | Shuttle run |
| One foot balancing on unstable platform, eyes open, multidirectional | Carioca crossover maneuvers |
| One foot balancing on unstable platform, eyes closed, multidirectional | Four-corner running |
| Active joint repositioning | Reaction cutting drills |
| Eccentric Loading | Eccentric Loading |
| Stair walking; forward and backward, up and down | Plyometrics (1–2 ft height) |
| Aerobic Conditioning | Aerobic Conditioning |
| Biking (if tolerated) | Running |
| Upper body ergometry | Remove crosstraining if running tolerated |
| Swimming | Phase IV |
| Phase II | Sport Specific Activities (performed at controlled speeds progressing toward normal speed) |
| Running | 4-corner running while dribbling |
| Figure-of-eight; large to small circles; slow to fast speed | Cutting of a minitramp while running pass route |
| Proprioception Training | Cariocas while defending |
| Cocontraction lateral slides | Sports specific drills removed from team setting |
| Minitramp hopping and jogging | Basketball layups |
| Pogo ball balancing and hopping | Fielding baseballs |
| Sport activity of unstable platform | Running and receiving footballs |
| Lateral slide board exercise | Defensive maneuvers for respective sports |
| Eccentric Loading | Aerobic conditioning |
| Plyometric exercises (6''–12'' heights) | Running |
| Stair running (if tolerated) | Phase V |
| Aerobic Conditioning | Functional Performance Testing |
| Biking | Cocontraction Test |
| | Carioca crossover Test |
| | Shuttle run Test |
| | Hop Test |
| | Figure-of-eight Test |

From Lephart SM, Borsa PA: Functional rehabilitation of knee injuries. In Fu, Harner, Vince (eds): *Knee Surgery*. Baltimore, Williams & Wilkins, 1994, pp 527–539; with permission.

knee during normal sports activity. Cutting and agility-proprioception activities are initiated during this phase and should be progressed to near normal speed by the conclusion of this phase. Activities such as the shuttle run are used for acceleration and deceleration training, while agility is trained by activities including the four-corner run, the carioca maneuver, and reaction cutting maneuvers. Reactive activities that require the athlete to react to visual or audible stimuli while running or jumping need to be incorporated. These types of activities serve to develop cutting and changing directions without programmed commands. Plyometrics should be continued and progressed while aerobic conditioning can be transferred to jogging at intensities within the training sensitive zone rather than cross-training activities.

Phase IV of the lower extremity functional rehabilitation focuses on the integration of the functional elements refined during the earlier phases of the program into sport-specific activities. This phase may include many activities and drills that are actually performed during a particular sport's practice session, although the athlete has not returned to actual competition or practice. The success of the sport-specific phase of the functional program depends on appropriately defining the specific demands of each athlete within their sport. Therefore, this phase of each sport-specific functional program is designed uniquely for each athlete.

It is imperative that each clinician understand the demands of each sport and of the athlete's pathology. Many of the phase-III agility and proprioceptive activities can be performed by incorporating sport-specific actions.



Figure 2. Kinesthetic training on an unstable platform for the lower extremity in the closed chain position; both feet

Examples include shuttle runs and figure-of-eight running while dribbling a basketball or soccer ball, cutting off of a mini-tramp while executing a pass route for a football receiver, and performing carioca activities while defending an opponent. Phase IV of the sport-specific program is the integration of specific drills and performance activities that the athlete will return to. Examples include layup and defensive slide drills in basketball, fielding and base running in baseball, pass receiving and defensive maneuvers in football, and the like. The athlete must perform the sport-specific activities in a controlled manner, and the speed and intensity of performance is determined by the athlete's motor skill development, functional joint stability, and confidence.²²

THE UPPER EXTREMITY FUNCTIONAL REHABILITATION PROGRAM

The functional rehabilitation program for the upper extremity is somewhat different from that of the lower extremity. The upper extremity follows a gradual progression through the exercises but does not involve the distinct phases of the lower extremity such as walking,

jogging, running, etc. It is important to mention once again that a muscle strength and endurance base are essential in providing the basis for dynamic stability of the upper extremity. Both open and closed kinetic-chain exercises will be used in this program. An emphasis on functional positioning is also important.

Weight-shifting activities should begin early in the functional rehabilitation program. These are used to enhance dynamic joint stability and may be enhanced with manual resistance. These exercises can be progressed from a solid base to an unstable platform. These types of activities include sudden alterations in joint positioning that necessitate reflex muscular stabilization. Rhythmic stabilization exercises that develop cocontraction and neuromuscular coordination of the rotator cuff and scapular muscles are very beneficial.¹⁶ These types of exercises can be performed in both open and closed kinetic-chain modes. The activities can be performed in the functional position of each joint. The unstable platform should produce a series of patterns that result in sudden changes in joint position and necessitate dynamic stabilization by the athlete to control the balance of the platform. The platform can be designed using an air bladder or a series of bearings that allow movements in all directions⁶ (Fig. 3).

Another form of functional activity that may be used early in the functional phase is passive and active joint repositioning. This will aid in developing an appreciation for joint position.⁶

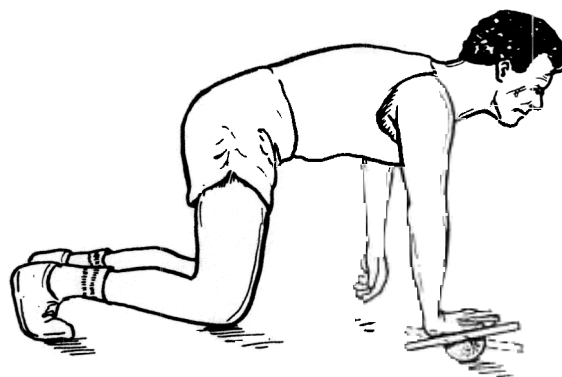


Figure 3. Kinesthetic training using an unstable platform for the upper extremity in the closed chain position (from "Functional Assessment and Rehabilitation of Shoulder Proprioception for Gleno-Humeral Instability" by PA Borsa, SM Lephart, MS Kocher, and SP Lephart, *Journal of Sport Rehabilitation*, (Vol 3; No. 1), pp 84-104. Copyright 1994 by Human Kinetics Publishers, Inc. Reprinted by permission).

These types of exercises should be performed in the functional position for each joint and emphasize the near end-ranges of motion. These activities are very simple, having the athlete reproduce given ranges of motion without visual input. Passive repositioning can be accomplished on a proprioception testing device or an isokinetic device. Passive repositioning will maximally stimulate articular mechanoreceptors, while active repositioning relies on input from both articular and muscle receptors.

Proprioceptive neuromuscular facilitation exercises are a common and very efficient mode of enhancing the response of the neuromuscular mechanisms by stimulating stretch receptors located on the muscle or tendon units.^{6,17} These types of activities involve a combination of spiral and diagonal patterns of movement that demand both neuromuscular coordination and strength (Fig. 4). The basis behind these activities is the reflex neural inhibition that occurs when a muscle is stretched.^{17,38} This reflex activity overrides the normal reflex contraction that is initiated when the muscle is stretched.³⁸ The reflex relaxation



Figure 4. Resistive tubing exercises in a functional position using PNF patterns; diagonal pattern 1: flexion, abduction, external rotation (from "Functional Assessment and Rehabilitation of Shoulder Proprioception for Gleno-Humeral Instability" by PA Borsa, SM Lephart, MS Kocher, and SP Lephart, *Journal of Sport Rehabilitation*, (Vol 3; No. 1), pp 84–104. Copyright 1994 by Human Kinetics Publishers, Inc. Reprinted by permission).

allows the muscle to stretch through relaxation before the extensibility limits are exceeded and damage to the muscle fiber occurs.

Plyometric type exercise can also be used to train the proprioceptive or neuromuscular mechanism. These types of activities use a quick, powerful movement that involves a prestretch or eccentric load of the muscle, followed by a shortening, concentric muscular contraction. This involves the stretch-shortening muscular cycle, more commonly referred to as the myostatic reflex.^{6,18} Plyometric exercises fit nicely into the specificity of training principle. These exercises should be implemented into the advanced stages of the overhead athlete's functional rehabilitation program. These can be divided into throwing motions, trunk motions, and ball/wall drills (Fig. 5A, B).

As mentioned previously, open kinematic-chain exercise is appropriate in upper extremity functional rehabilitation, especially with throwing athletes. Throwing occurs in the open kinematic-chain-position and open-chain exercise is imperative to develop functional stability throughout the throwing motion.

Isokinetic exercise is another mode that is often used in the functional rehabilitation program (Fig. 6). In the upper extremity, it is suggested that the use of isokinetics be performed in functional positions. For a throwing athlete, the most functional position would be at approximately 90 degrees of abduction and 90 degrees of elbow flexion. In this position, concentric and eccentric exercise of the internal and external rotators would be most appropriate. High-speed isokinetic exercise may be incorporated in these positions to begin development of higher rates of muscular contractions in the functional movements.

Throwing athletes should also incorporate a throwing regimen into their functional program. There are many throwing programs available but the basic principles are very similar in each. The program will alternate throwing days with rest days. The throwing would begin with long, soft tosses for a very low number of throws. This period may last for up to 2 to 3 weeks. The program would gradually increase the number of throws and eventually the intensity and length of the throws. A large emphasis must be placed on proper throwing mechanics throughout the throwing program.²⁸

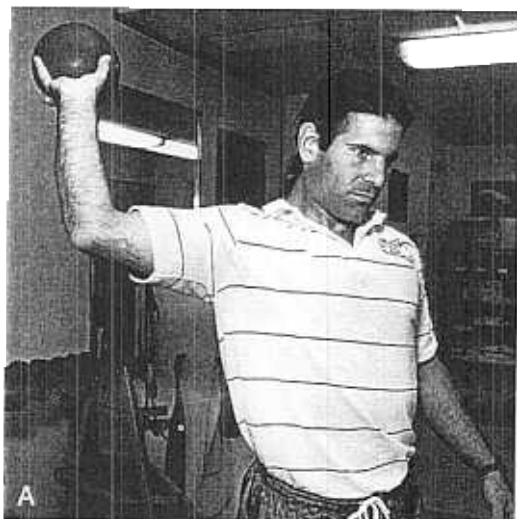


Figure 5. Plyometric exercise: (A) throwing motions; (B) push-up boxes (from "Functional Assessment and Rehabilitation of Shoulder Proprioception for Gleno-Humeral Instability" by PA Borsa, SM Lephart, MS Kocher, and SP Lephart, *Journal of Sport Rehabilitation*, (Vol 3; No. 1), pp 84-104. Copyright 1994 by Human Kinetics Publishers, Inc. Reprinted by permission).

FUNCTIONAL PERFORMANCE TESTING AND RETURN TO SPORTS

Lower Extremity

Assessment of the athlete's functional capacity and readiness to return to sport is a very important issue. It is imperative that the clinician have some objective measure to assess the athlete's functional capacity. The premature return to sport of an injured athlete can have very dangerous and devastating consequences. Recurrent injury is the most severe, and the chance for reinjury needs to be minimized. Herein lies the importance of functional performance testing.

Until recently, functional rating scales have been used to assess functional capacity.^{7,20,21,22,32} These, however, have been refuted based on the lack of a strong relationship between actual physical characteristics and functional scores.²² Lephart et al,²⁷ Walla et al,⁴⁹ and Tegner et al⁴⁴ showed a relatively poor relationship between the selected physical characteristics and functional measurements that were assessed in lig-



Figure 6. Upper extremity isokinetic Open Kinematic Chain Exercise (Biodex Medical Systems, Inc. Shirley, NY)

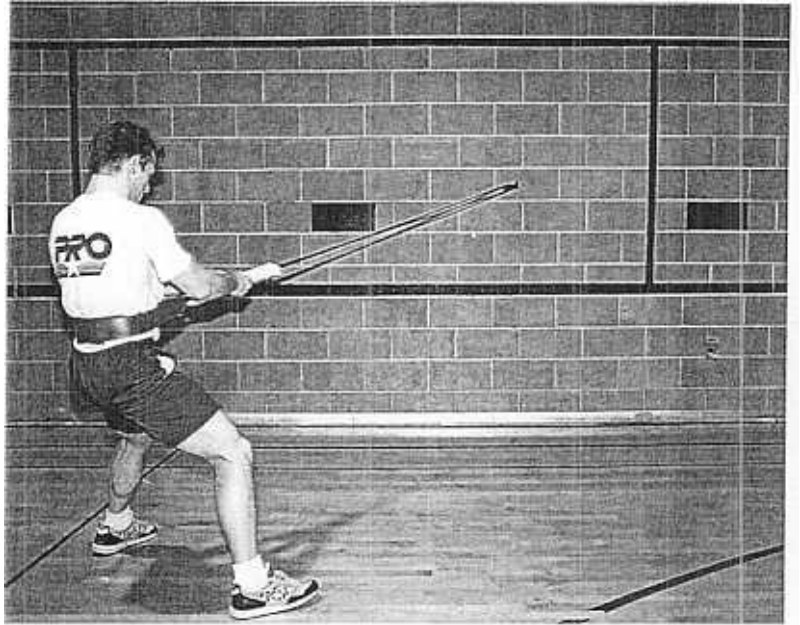


Figure 7. Co-contraction Test: the athlete moves laterally around the periphery of a semicircle (from Lephart SM, Borsa PA: Functional rehabilitation of knee injuries. *In* Knee Surgery. Baltimore, Williams & Wilkins, 1994 pp 527—539; with permission).

ament-deficient and reconstructed athletes. Isokinetic testing has also been a common mode of assessing an athlete's functional capacity. This is usually performed in an open kinetic-chain system in a non-weight-bearing state.²² It is suggested that the use of such instrumentation is inappropriate to assess the compensatory role of this musculature because of the inability to reproduce normal knee joint kinematics that occur in a closed-chain system.²⁷

Lephart²⁶ has developed a series of functional performance tests that give an objective measurement of function by reproducing the activities required to perform common sport skills and by simulating jeopardizing stresses placed on the lower extremity to assess dynamic stability. The test include a cocontraction semicircular maneuver (Fig. 7), a carioca maneuver (Fig. 8), and a shuttle run (Fig. 9). These tests were designed to produce rotational forces at the knee, tibial subluxation, and acceleration and deceleration respectively. All three tests are performed for time, which assesses confidence while performing the maneuvers and is independent of skill. In our studies, those athletes who were able to return to preinjury levels of sport activity performed significantly better on the functional performance tests than those athletes who were unable to return to preinjury activities. Thus, high levels of performance in these tests are related to a return to preinjury levels of activity. These functional performance tests allow the clinician to

objectively quantify performance while also visually assessing such factors as running gait, compensation, and apprehension.^{26,27}

In addition to the previously described, functional tests by Lephart,²⁶ Daniel et al⁷ and

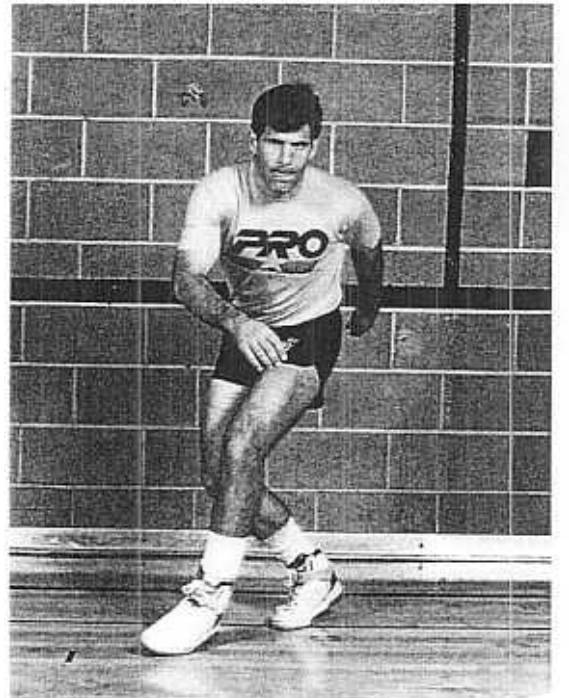


Figure 8. Carioca test: the athlete moves laterally using an alternating crossover step.



Figure 9. Shuttle run test.

Barber et al¹ suggest the use of single leg-hop test for assessment of ACL deficient or reconstructed athletes. The one leg hop for distance, the timed hop, and the triple hop for distance provide a good clinical assessment of the athlete's strength and willingness to land on the affected limb. These tests use the contralateral limb for comparison and can be performed in an area with restricted space. Barber et al¹ showed that an abnormal hop test result is an

indicator that the patient may be at risk for giving-way during sports activities.

Tegner et al also has suggested functional performance tests including the figure-of-eight running, running up and down a slope, and running up and down a staircase.^{44,45} The results of their work indicate the hopping and running straight provide a controlled assessment that often will not identify functional deficiencies, but more specific activities that include cutting and turning place greater demands on the knee and are more sensitive to identifying functional deficiencies.^{44,45}

Recently, objective balance assessments for the lower extremity have become available. These types of instruments involve balancing on a platform that can become unstable and measure both static and dynamic balance in the lower extremity (Fig. 10A, B). The instruments provide objective balance indices that can be useful in quantifying an athlete's proprioceptive/kinesthetic level.

Upper Extremity

The return to participation of the upper extremity injured athlete is not quite as defined as the lower extremity. Very few objective assessments have been developed for the upper extremity that can give the clinician a valid indication of the athlete's functional level. Theoretically, the athlete can return to their respective sport activity when they have full motion,

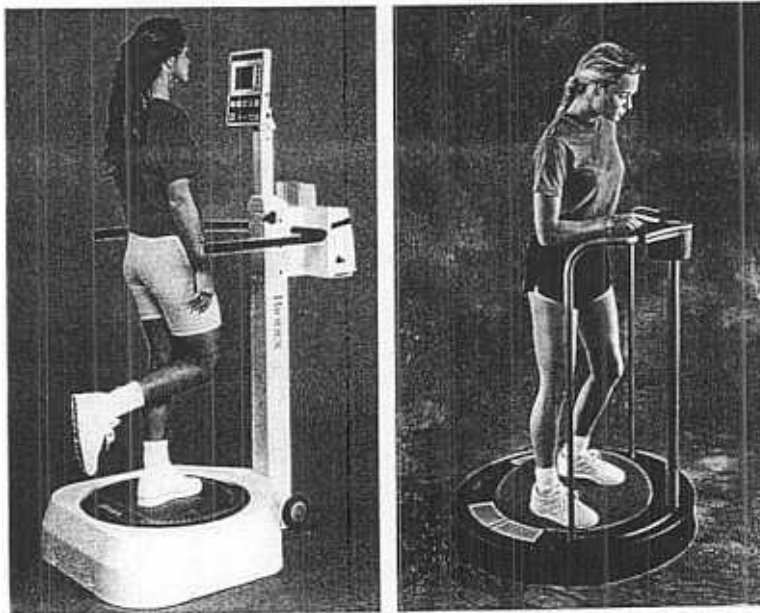


Figure 10. Kinesthetic and proprioception training on instrumented stableometry unit. (A) Biodex Stability System (Biodex Medical Systems, Inc., Shirely, NY); (B) Kinesthetic Ability Trainer (KAT, Breg Inc., San Marcos, CA).

normal strength, and confidence in the injured extremity. Progression through a functional rehabilitation program such as the one described here will help to best prepare the upper extremity athlete to safely and confidently return to a high level of functional activity.

SUMMARY

Functional rehabilitation is an extension of the traditional elements of physical therapy, the purpose of which is to return the athlete to highly complex movement patterns such as athletics. As well as the traditional elements of physical therapy such as strength and flexibility, the functional rehabilitation program incorporates agility and proprioceptive/kinesthetic training, which enables the athlete to participate at preinjury levels of activity while reducing the risk of recurrent injury. The functional rehabilitation program is designed to progress the athlete from simple activities, such as walking or jogging, to highly complex sport-specific activities that require refined levels of proprioceptive acuity. The final phase of the functional rehabilitation program is determining when the athlete is ready to resume participation in their respective sport. This is a very important and sometimes overlooked component of the functional rehabilitation program. The decision for returning an athlete to participation should be made using objective assessments of function that simulate sport activity whenever possible. Last, return to sport activity should be done gradually. Progression into the sport activity is essential to a full and healthy return to participation.

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