AQUATIC THERAPY IN THE REHABILITATION OF ATHLETIC INJURIES

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Increasing interest in aquatic physical therapy can be attributed in part to its evolution from the limited confines of spas and "Hubbard tanks," to the larger venues of swimming pools. These larger exercising areas accommodate a greater variety of exercises, including those that require sustained propulsive movements.

Using the water to regain lost mobility and strengthen weakened muscles has been described by a number of authors.[9, 19, 20, 31, 35] The purpose of this article is to discuss the manner in which aquatic physical therapy is used for the treatment of common athletic injuries.

PHYSICAL PROPERTIES OF WATER AFFECTING AQUATIC PHYSICAL THERAPY

Two important physical properties of water, buoyancy and viscosity, are key elements in designing effective exercises for treating athletic injuries. The advantage of buoyancy is direct: When a person enters the water, there is an immediate reduction in the effects of gravity on the body. The advantage of viscosity of water is indirect: When the person moves through the water, resistance is felt. The degree of effort is determined by the size of the moving body, or limb, plus the speed or velocity of the movement.

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Force of Buoyancy and Its Effect on Weightbearing During Immersion

The buoyant force of water decreases the effective weight of an individual in proportion to the degree of immersion. Axial loading on the spine and weight-bearing joints, particularly the hip, knee, and ankle, is reduced with increasing depths of immersion (Fig. 1).[14] When standing in chest-deep water, the weight-bearing load is approximately 40% of the total body weight, whereas stepping on a submerged step (waist-deep water) increases the weight-bearing value to approximately 60%.[14]

The ability to control joint compression forces by varying degrees of immersion is of primary benefit in the design and prescription of therapeutic exercises. By monitoring the depths at which functional movements, such as walking and stepping, are performed, the effect of gravity can be reintroduced and, consequently, gradual strengthening is promoted.[31, 41] When floating in prone, supine, or vertical positions, the effects of gravity are eliminated.

Muscle Strengthening Using the Viscosity of Water

Although traditional modes of strength training have been used successfully in clinical settings, there are three primary advantages for using water resistance to promote strengthening.

Water Acts as an Accommodating Resistance

The advantage of accommodating resistance is that it matches the patient's applied force or effort. Because the resistance of the water equals the force exerted, the likelihood of exacerbation or reinjury is reduced dramatically.

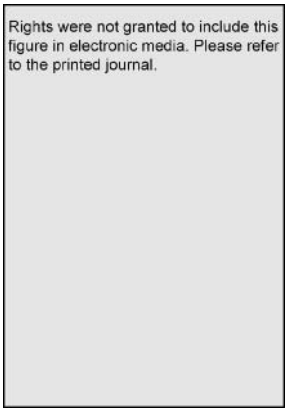


Figure 1. Subject's weight-bearing load is 40% (chest depth) and increases to 60% (waist depth) when standing on the step.[14] (Courtesy of Prins Aquatherapy, Inc., Honolulu, HI.)

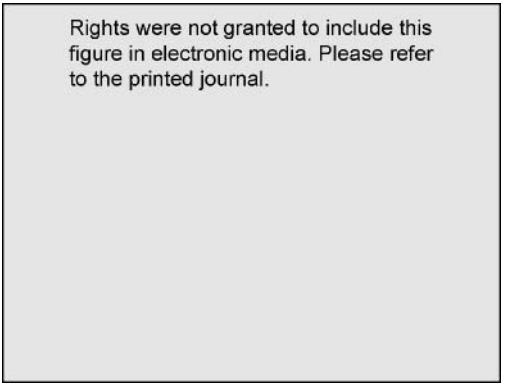


Figure 2. Buoyant force of foam bell is used to assist with increasing shoulder range of motion. (Courtesy of Prins Aquatherapy, Inc., Honolulu, HI.)

Water Acts as a Variable Resistance

The term variable refers to being able to change the speed or velocity of the movement. Unlike isokinetic strength-training apparatus, which limit exercises to a preset velocity, it is possible to change limb speeds during each repetition in the water. Because most human motion is variable in nature, functional gains are more likely to be made.

Strengthening Exercises in Water Are Unrestricted in Direction and Limited Only by the Mobility of the Joints Being Used

One limitation of conventional strength-training apparatus is that joint activity is isolated.[31] Many exercise machines are designed with rigid bars that guide the resistance; this limits the user to exercising in fixed planes of movement. In contrast, aquatic strengthening exercises can be designed to closely match everyday movements and, as a result, provide neuromuscular adaptations better suited to the activities of daily living. In an attempt to quantify the applied muscular forces in water, pressure-sensitive sensors have been designed to measure the patient's progress. The results of monitoring lower extremity strength during the course of aquatic therapy treatment following anterior cruciate ligament (ACL) surgery are listed in Table 1.

BENEFITS OF AQUATIC REHABILITATION

In addition to points discussed in the previous section, there are other applications of properties of water used in treating athletic injuries.

Using Buoyancy to Increase Range of Motion

An array of clinical conditions, such as subacromial bursitis, calcifying tendinitis, and partial rotator cuff tears, are included in the term "frozen shoulder syndrome."[26] These conditions, which restrict active and passive glenohumeral and periscapular shoulder motion, can be treated in water by taking advantage of the force of buoyancy to promote both active and passive movement.[2, 15, 26, 35] Varying the standing depth controls the amount of movement of the upper extremity (Fig. 2). Other types of flotation equipment can be used to assist with movements of the lower extremity.

Table 1. RESULTS OF AN 8-WEEK AQUATIC PHYSICAL THERAPY PROGRAM FOR RECOVERY FROM LEFT ANTERIOR CRUCIATE LIGAMENT (ACL) INJURY

	Right	Left (injured)	% Deficit
Test 1: (12 weeks postsurgery)	87.8 N	69.2 N	21.9
Test 2: (20 weeks postsurgery)	85.6	78.8	7.9

Peak forces in Newtons (N) against water was measured for single-leg standing flutter kick using pressure sensors. A reduction in the deficit for peak force between the injured and noninjured knee is seen after the 8-week program.[27]

Cooperative Movements of Upper and Lower Extremities

An often overlooked advantage of aquatic physical therapy is the extensive range of exercises that require alternating or symmetric movements of the limbs and associated joints. These movements encourage increased involvement of the affected limbs by inducing the injured side to match the effort and range of motion of the uninjured side. The propulsive movement patterns of formal swimming strokes require arm and leg actions that combine symmetric or alternating patterns of motion.

Cardiorespiratory Fitness in Water

The loss of cardiorespiratory fitness can be significant during recovery after injury; early resumption of exercise, therefore, now is considered essential to the successful return to preinjury activity. Aquatic therapy allows the injured athlete to begin exercising earlier. Deep-water running has been shown to compare favorably with land-based exercise.[5, 30, 34, 40] Maximum oxygen uptake (VO_{2max}) values for aquatic running range from 83% to 89% when compared with the values obtained from running on land. Maximum heart rate values for aquatic running ranged from 89% to 95% of values measured on land.[3, 4, 34, 36]

Aquatic running, when supported by a floatation device, offers additional benefits, most notably the maintenance of quick turnover (rapid gait cycling), and coordinated movements between the arms and legs. These aspects facilitate the return to land-based training.

Early Restoration of Joint Mobility

Prolonged rest or inactivity following injury is no longer recommended for patient recovery. The therapeutic advantages of early restoration of joint mobility are well documented.[2, 14, 18, 21, 40] The inactive injured athlete is predisposed to muscle atrophy, soft tissue weakness, decreased joint mobility, and possible increases in pain.[17, 24, 35, 38, 39] Also, functional deficits may be addressed sooner with early mobilization.[16, 21]

Water provides a low-stress physical environment where axial and compressive forces are reduced; thus, a case can be made for early prescription of aquatic therapy.[11, 17, 31] When full weight-bearing activities are premature but closed kinetic chain exercises are recommended, exercising in the water at graduated depths is ideal.[17, 31] Individuals recovering from back, hip, and knee injuries or surgery can benefit from beginning therapeutic exercises in the supportive aquatic environment.[20, 23] Patients with multiple injuries also benefit from starting a strengthening and joint mobilization program in the water, making a later transition to land-based physical therapy, to continue their prescribed rehabilitation program.

OVERVIEW OF AQUATIC EXERCISES

A wide variety of aquatic exercises are employed for strengthening and increasing joint range of motion. When designing an exercise program it also is important to consider such factors as pathology, age, body type, and the patient's comfort level in the water.

Primary Body Positions Used in Aquatic Rehabilitation

A typical aquatic exercise program combines exercises that are performed in several body positions.

Standing on the Bottom of the Pool

Most standing exercises are performed at depths between midchest (xyphoid) and the top of the shoulder (coracoid process). Two factors to be considered when designing exercises in the standing position are

The depth of water in which exercises are performed. This determines the degree to which buoyancy will affect the percentage of weight bearing on joints and range of motion.

Buoyancy. There is a positive force when moving toward the surface of the water and an opposing or negative force when moving away from the surface.

Walking and Associated Stepping Patterns

Walking at different depths provides an invaluable method of reintroducing the mechanics of gait while varying the axial loads on the spine, hip, and joints of the lower extremities. The mechanics of gait can be simulated without the risks associated with gravitational forces and the loss of balance. An added benefit is the increased muscular effort needed to move through a denser medium.

Differences in the gait phases are apparent when patients of different body densities walk at varying depths. Decreased stride lengths often characterize initial gait patterns. A decrease in hip and knee flexion results in a shuffling of the feet during the swing phase of the gait cycle. In some cases, exaggerated hip and knee flexion may occur.

It must be remembered that the degree of ground reaction force that can be maintained when submerged at different depths will establish the amount of contact between the foot and pool bottom. In turn, the amount of contact will determine the effectiveness of the propulsive phase of each stride.

Floating on the Surface

Flotation devices allow the body to remain motionless, eliminating the need to apply propulsive forces to remain on the surface. This allows the gradual introduction of upper and lower extremity movements for both flexibility and strengthening.

Floating vertically in the water. For most individuals, a floatation vest is necessary to float vertically in deep water. Therapeutic exercises in this position range from passive vertical traction with weights attached to the ankles, to a variety of exercises involving movements at the hip, knee, and ankle joints. Hip, knee, and ankle movements in the cardinal and oblique planes can be performed in the absence of all gravitational forces. Running movements of varying stride lengths and frequencies can be simulated. Alternating leg movements that resemble the "flutter kick" of the front crawl are also performed in this position. This kick pattern strengthens the quadriceps muscles and promotes strengthening of the hip and lower lumbar regions.

Floating prone or supine. Floating horizontally with the aid of floatation

and breathing devices (mask and snorkel) can be used to reduce the tension accompanying soft tissue injury, principally in the neck and lower back.

Floating prone. Exercises for strengthening both upper and lower body segments can be performed in the prone position, that is, floating face down in the water, wearing a mask and snorkel. Selected arm and neck movements can be prescribed for cervical, glenohumeral, and shoulder girdle strengthening. Specific kicking movements are used when the focus is the lumbar spine, hip, and lower extremities. Also, there are many variations of formal swimming strokes that can be performed when lying prone in the water.

Floating supine. Although upper extremity movements in this position are limited in comparison to floating prone, lower extremity kicking patterns are somewhat similar. The major advantage of floating in the supine position is the ability to place the body in varying degrees of extension or hyperextension. Spine specialists have noted that the preferred position for persons with discogenic pain is in a slight "extension bias."[9] With proper adjustment of the floatation vest, the degree to which the spine is placed in extension can be adjusted (Fig. 3).

DESCRIPTION OF INJURIES AND RECOMMENDED AQUATIC REHABILITATION EXERCISES

Each anatomic area covered below includes a list of typical athletic injuries, descriptions of aquatic rehabilitation exercises recommended as part of treatment, and equipment suggestions.

Shoulder Girdle and Glenohumeral Joint

The complexity of the shoulder joint, together with its importance in most athletic endeavors, leaves it vulnerable to injury. Injuries at this joint result from single traumatic events or repetitive overuse situations.[1, 32] The most common traumatic injuries are fractures, tears, subluxations, and dislocations. Rotator cuff impingement, inflammation of the tendons and bursa, and joint instabilities are the primary consequences of excessive use of the shoulder.[6, 22] Swimming,

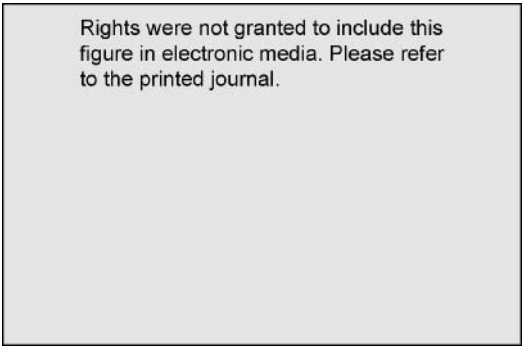


Figure 3. Positioning of flotation vest will determine degree of spinal extension in supine floating position. (Courtesy of Prins Aquatherapy, Inc., Honolulu, HI.)

tennis, and throwing activities, such as baseball pitching, are listed as activities that are likely to cause these conditions.[28, 29]

Strengthening of the shoulder girdle and glenohumeral joint can be performed in the water, using a variety of body positions (Table 2). The available planes of movement and the desired range of motion determine the choice of body position. Resistive force is a function of the cross-sectional area of the limbs and resistive device, if used, and the speed at which the movement takes place.

Equipment for Shoulder Exercises

Hand paddles and hand-held three-dimensional resistive devices commonly are used for strengthening the upper extremities. These devices come in a wide range of shapes and sizes and help increase the cross-sectional area of the moving limb.

Elbow and Radioulnar Joint

The combination of weak lateral bony arrangements and a broad range of motion predisposes the elbow and radioulnar joints to injury in many different sports. Injury to the elbow from direct blows can cause contusions, dislocations,

Table 2. EXERCISES FOR INCREASING JOINT MOBILITY AND RANGE-OF-MOTION OF THE SHOULDER

1. Passive stretching exercises in the water	
2. Active range-of-motion exercises	
Standing upper extremity movements	• Flexion extension • Abduction/adduction • Internal/external rotation • Horizontal abduction/adduction
Floating prone	• Flexion/extension • PNF patterns • Horizontal abduction/adduction
Exercises for increasing strength of the shoulder	
Standing upper extremity movements	• Flexion/extension • Abduction/adduction • Internal/external rotation • Horizontal abduction/adduction
Floating prone	• Flexion/extension • PNF patterns • Horizontal abduction/adduction
Swimming strokes	• Breaststroke pull patterns performed at different depths with respect to the surface • Underwater freestyle (alternating front-crawl pull patterns without overarm recovery) • Elementary backstroke starting at varying degrees of abduction • Formal swimming strokes can be introduced or reintroduced in the case of persons returning to training in the water

Table 3. EXERCISES FOR INCREASING JOINT MOBILITY AND RANGE-OF-MOTION OF THE ELBOW AND RADIOULNAR JOINT

1. Passive stretching exercises in the water	
2. Active range-of-motion exercises	
3. Exercises for increasing strength of the elbow and radioulnar joint	
Standing upper extremity movements	• Push/pull action • Flexion/extension • Pronation/supination (Fig. 4)
Floating prone	• Flexion/extension • PNF patterns • Horizontal abduction/adduction

fractures, and soft tissue damage. Overuse injuries to the elbow area are often a result of excessive throwing activities and sports that require swinging of bats, clubs, and rackets.[1, 32] Table 3 lists exercises for increasing mobility, range, and strength of this area.

Equipment for Elbow and Radioulnar Joint Exercises

Hand paddles and hand-held three-dimensional resistive devices may be used for these exercises (Fig. 4).

Wrist and Hand

Wrist injuries are common in sports, such as football, basketball, soccer, and volleyball. Repetitive pushing, blocking, spiking, or falling on an outstretched arm are common causes of these injuries. Recommended aquatic physical therapy exercises for the wrist and hand are similar to those used for the elbow.

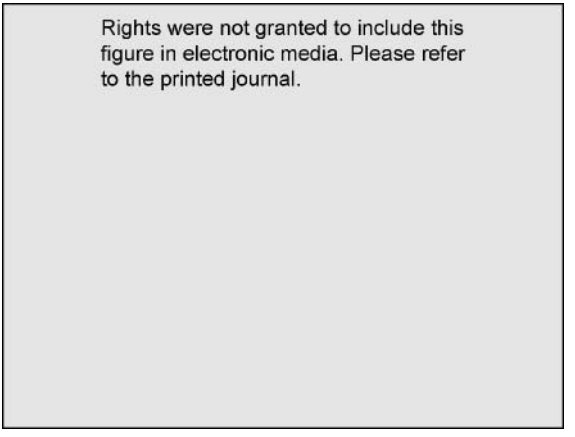


Figure 4. Pronation/supination exercise, performed using spatulas. (Courtesy of Prins Aquatherapy, Inc., Honolulu, HI.)

Cervical Spine

Injuries to the cervical spine can occur from direct trauma and range from fractures to sprains and strains. These injuries usually involve forceful hyperflexion and extension, rotation, and lateral flexion. Collisions, as in tackling, spearing, and diving, and combinations of twisting and lateral flexion, are seen in sports, such as football, wrestling, soccer, and the martial arts.[1, 32]

At present, aquatic exercises for strengthening the cervical and thoracic regions are those that involve concomitant strengthening of scapula stabilizers and glenohumeral musculature. In addition to exercises performed in the primary planes of motion, movements in oblique planes of motion, such as the sculling pull patterns seen in selected swimming strokes, are ideal (Table 4).

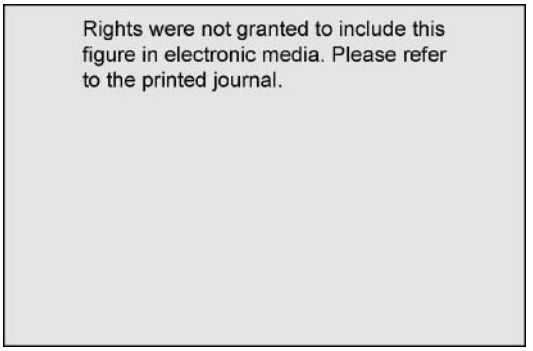
An added advantage of the water is the option of performing many neck strengthening exercises while floating in the prone position. When a mask and snorkel are used for breathing in the prone position, the buoyant force of the water can be relied on to support the weight of the head. This relieves injured muscles and associated soft tissue from the responsibility of counteracting anticipated gravitational forces (Fig. 5).

Equipment for Cervical Exercises

Hand paddles and hand-held three-dimensional devices also are used for strengthening the upper extremities. Many of the available resistive devices can be modified to increase the amount of resistances.

Table 4. EXERCISES FOR INCREASING CERVICAL JOINT MOBILITY AND RANGE-OF-MOTION

1. Passive stretching exercises in the water	
2. Active range-of-motion exercises	
Standing on the bottom of the pool	• Cervical flexion/extension • Cervical rotation • Cervical lateral flexion • Chin-tuck exercises
Suspended vertically in deep water	• Cervical traction
Exercises for increasing cervical strength	
Standing	• A series of unilateral and bilateral arm exercises with and without the use of resistive apparatus. Exercises similar to those used in shoulder strengthening
Floating prone	• Flexion/extension • PNF patterns • Horizontal abduction/adduction (Fig. 5)
Swimming strokes	• Breaststroke pull patterns performed at different depths with respect to the surface • Underwater freestyle (alternating front-crawl pull pattern without overarm recovery) • Elementary backstroke starting at varying degrees of abduction • Formal swimming strokes can be introduced or reintroduced in the case of persons returning to training in the water



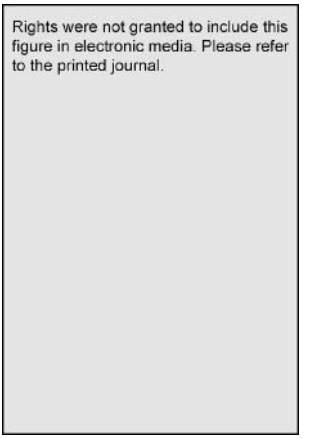


Figure 5. Upper extremity abduction/adduction exercises, using resistive hand paddles, performed in the stationary prone position, provide maximum resistance in both directions of the movement. (Courtesy of Prins Aquatherapy, Inc., Honolulu, HI.)

Figure 6. Isometric spine stabilization exercise, using a tray. (Courtesy of Prins Aquatherapy, Inc., Honolulu, HI.)

Lumbar Spine

As in the case of the cervical spine, injuries to the lower back can be attributed to repeated stresses or a single traumatic occurrence. Congenital conditions also may play a role in these events; however, almost all athletic activities place demands on the lower back and consequently can precipitate injury.

When dealing with injuries to the spine, particularly the intervertebral disks, aquatic treatment must focus on effective spine stabilization protocols.[8,9] Aquatic stabilization techniques help the patient regain dynamic control of segmental spine forces and eliminate repetitive injury to the motion segments.[9] Exercising at different standing depths provides an important process for adjusting the compressive and shear forces on the spine.

The effectiveness of aquatic spine stabilization exercises (Table 5) is based on the premise that in order for the upper and lower extremities to generate muscular forces, the axial skeleton, particularly the lumbar spine, must provide a stable base of support. This fulcrum, or stable base, is produced by isometric contractions of the abdominal and spinal muscles, with corresponding tension provided by the ligaments and associated structures, such as the thoracolumbar fascia.

Equipment for Lumbar Spine Exercises

Resistive fins, preferably of short-blade design, provide moderate increases in resistance. Trays of different sizes can be used for standing and walking exercises (Fig. 6). Although a number of patterns for flotation vests are available, those that are rectangular in shape are recommended.

Table 5. EXERCISES FOR INCREASING LUMBAR SPINE JOINT MOBILITY AND RANGE OF MOTION

1. Passive stretching exercise in the water	
2. Active range-of-motion exercises	
Standing on the bottom of the pool	• Gluteus maximus stretch • Adductor stretch • Hamstring stretch • Piriformis stretch • Gastrocsoleus stretch
Floating prone	• Selected stretches may be performed while floating prone, for example, double knee-to-chest stretch
Floating vertically	• Vertical traction with ankle weights attached to the ankles
Exercises for increasing lumbar spine strength	
Standing against or away from wall	• Unilateral hip flexion/extension • Unilateral leg movements simulating the flutter-kick • Unilateral abduction/adduction • Push/pull and/or sideways movements using a tray (Fig. 6)
Walking on the bottom of the pool at different depths	• Forward/backward walking
Floating vertically, body position maintained with the aid of a floatation device	• A series of lower extremity movements, similar to those performed while standing. However, the exercises now can be performed with both legs working simultaneously, as in the case of the flutter-kick or abduction/adduction
Swimming strokes	• Swimming and kicking in the prone and/or supine body positions, maintaining a neutral spine. • Stroke mechanics must be modified to fit patient's experience and tolerance

Knee

Much has been written about stresses placed on the knee joint in athletics.[1, 32] Because joint reaction forces on the knee can reach several times body weight, aquatic rehabilitation reduces negative consequences of gravitational and compressive forces, allowing safe and effective therapy.[35, 37] Studies have recommended a combination of open- and closed-chain exercises for increasing quadriceps and hamstring strength during acute and intermediate postoperative periods following ACL reconstruction.[18] An 8-week study comparing aquatic physical therapy with traditional land-based therapy was conducted for patients recovering from ACL reconstructive surgery. Although no difference in passive range of motion was found between the two groups, the group treated in the water showed less joint effusion, reported greater functional improvement, and recorded higher scores on the Lysholm scales (a measure of functional stability of the knee joint).[35]

In the water, functional activities, such as walking at varied depths, that affect the percentage of weightbearing, can be started earlier than on land. When

open-chain exercises are prescribed, using water as an accommodating resistance medium eliminates risks associated with excessive muscle force or loading of the joint. The strengthening exercises in Table 6 can be accompanied by normalization of range-of-motion by taking advantage of the buoyant force of water.

Equipment for Knee Exercises

Resistive fins, preferably of short-blade design, provide increases in resistance.

Hip, Thigh, and Foot

Aquatic treatment of injuries to the hip, thigh, and foot incorporate those exercises described for rehabilitation of the knee. The effectiveness of closed-chain activities in the pool depends upon adequate traction between the foot and the pool surface.

RECOMMENDATIONS FOR IMPLEMENTING AN AQUATIC PHYSICAL THERAPY PROGRAM

For effective therapy, objective measurement of progress is essential. This is accomplished as follows:

1. An initial evaluation is conducted by a licensed physical therapist. This

Table 6. EXERCISES FOR INCREASING KNEE JOINT MOBILITY AND RANGE OF MOTION

1. Passive stretching exercises in the water **2. Active range-of-motion exercises**	
Standing on the bottom of the pool	• Quadriceps stretch • Hamstring stretch • Gastrocsoleus stretch
Exercises for increasing knee strength	
Standing against or away from wall	• Unilateral knee flexion/extension • Unilateral leg movements simulating the flutter kick • Step-ups, minisquats, and single-leg balance
Walking on the bottom of the pool at different depths	• Forward/backward walking • Marching
Floating vertically	• Aqua-jogging
Body position maintained with the aid of a floatation device	• Vertical bicycling • Vertical flutter kick • Vertical abduction/adduction
Swimming strokes	• Swimming with the emphasis on kicking action, in the prone and/or supine body positions. The resistive force can be increased by increasing rate or cadence, and by using resistive fins

evaluation provides objective measurement of strength, range of motion, posture, neurologic integrity, and function.
2. Following the initial evaluation the patient is given an aquatic assessment. The patient performs an established sequence of movements in the water, which are closely observed from the pool deck and recorded with underwater video equipment. The use of video technology provides a means for recording and analyzing subtle changes in movement mechanics, which can dramatically affect a patient's condition.
3. Changes in strength may be monitored by measuring the applied forces, using specially designed pressure-sensitive sensors.[27] This new technology is useful particularly for evaluating the efficacy of rehabilitation and the expected strength changes following surgery or injury induced inactivity.
4. The exercises, number of repetitions performed, or duration of the exercise effort is recorded at each therapy session to monitor increases in volume and intensity of the prescribed exercise workloads.
5. The therapist continually supervises and evaluates patient performance and status as a means of determining when to increase the exercise workload.

WHEN IS IT APPROPRIATE TO SELECT AQUATIC PHYSICAL THERAPY?

In determining whether aquatic or land-based therapeutic exercises should be prescribed, three options have been described.[9]

"Wet-to-Dry" Transition

Starting with aquatic therapy and then transferring to land-based therapy is recommended when strengthening joint areas are affected by axial and compressional forces. For example, aquatic therapy can be used when one is recovering from back, hip, and knee injuries. Strengthening can be accomplished more gradually in the water, in preparation for resuming land-based activity.

"Dry-to-Wet" Transition

Therapy is initiated with land-based exercises, and then the patient is transferred to aquatic therapy. This scenario is necessary when land-based exercises exacerbate the patient's condition. Once sufficient strength gains are realized, land-based activity can be resumed.

"Wet Only"

Exclusive use of aquatic therapy is recommended for patients who have an inability to tolerate land-based strengthening exercises, or by personal choice, prefer aquatic therapy.

CONCLUSIONS

The key to effective rehabilitation is the return to desired functional activity as soon as possible. Aquatic therapy provides a unique environment for promoting normal movement patterns and building strength early in the course of treatment. These changes usually are accomplished in the water, where the risk of further injury is reduced. This frequently is accompanied by a reduction in pain and perceived discomfort. Aquatic therapy in many cases is the only option for rehabilitation when land-based programs have not provided satisfactory results.

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