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# Aquatic Therapy to Improve Balance Dysfunction in Older Adults

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Balance dysfunction and falls-related injuries represent serious public health issues, resulting in great expense and human suffering. The physical problems leading to balance dysfunction include musculoskeletal-related structural limitations, diminished sensory capabilities, motor coordination deficits, and loss of anticipatory control mechanisms. The water has been described as an effective environment for addressing balance dysfunction through both rehabilitation and fitness activities. This article describes the underlying physical problems leading to balance dysfunction, provides a rationale for using aquatic therapy to positively influence balance control, and presents evidence to support the use of aquatic therapy for the management of balance dysfunction. **Key words:** *aquatic exercise*, *balance*, *falls*, *older adults*

BALANCE, or postural control, can be described as the ability to control one's body position in space for the dual purposes of stability and orientation.[1] A person's balance is not regulated by a single system but emerges from the interaction of many body systems. These systems include musculoskeletal factors (eg, joint range of motion [ROM], muscle tone, muscle strength), sensory factors (eg, ability to accurately perceive and respond to visual, vestibular, and somatosensory input), and neuromuscular strategies (eg, using appropriate postural strategies in a timely and effective manner) and anticipatory control (eg, pretuning sensory and motor systems in expectation of postural demands based on previous experience and learning). Figure 1 provides a conceptual model of how these systems must work in unison for the control of balance and posture. Balance dysfunction arises when changes to 1 or more of these systems limit an individual's ability to control his or her body position in space. The system changes that accompany the normal aging process (eg, vision loss, joint changes) can be detrimental to balance skills. These problems can be compounded by medical conditions that are more prevalent with older adults (eg, stroke, Parkinson disease, and vestibular dysfunction).

Several authors have described typical changes in the musculoskeletal systems of older adults.[2-6] One such musculoskeletal change is abnormal alignment of the body over its base of support (BOS). Disturbed body alignment can be brought about by such problems as range-of-motion limitations (eg, hip flexion contractures) or uneven weight distribution in sitting, standing, or walking (eg, when after a stroke, a person shifts his or her weight away from his or her more affected leg when walking). Changes in muscle structure and function can also result in abnormal musculoskeletal system function. For example, spastic muscles have a low threshold to stretch and respond in an exaggerated fashion to perturbations. Also, weak muscles may respond to a perturbation too slowly or with inadequate force to prevent a fall.

A variety of sensory system problems can lead to balance dysfunction in older adults.[7,8] In normal situations, an individual relies on an interaction between visual, somatosensory, and vestibular input to coordinate balance

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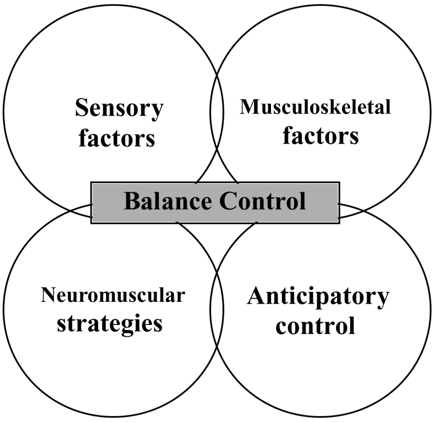


**Figure 1.** Conceptual model for major systems contributing to balance control.

responses. At times, the loss of one of these sensations can be compensated for with heavier reliance on one or both of the remaining sensory systems. However, if the remaining sensory systems are already compromised, the ability to compensate may be inadequate to prevent a fall. At other times, a person may be unable to integrate conflicting sensory information to produce an effective postural response.

Motor control research has identified stereotypical postural reactions to specific types of external challenges.[1] For example, when external forces move the body to sway forward, it often recovers using an ankle strategy that is characterized by activation of the gastrocnemius muscles, then the hamstring muscles, and then the paraspinal muscles. In order for this postural synergy to prevent a fall forward, the appropriate muscles must activate at the right time, in the correct sequence, and with the appropriate force. Older adults often encounter difficulties in recruiting the appropriate postural responses to a task or environmental demand.[8] Neuromuscular strategy problems that lead to balance dysfunction include recruiting muscles out of sequence, a delayed response in recruiting a muscle or group of muscles, cocontraction of antagonist muscles, and problems scaling the amplitude of a muscle response.

Balance dysfunction in older adults has also been linked to the loss of anticipatory control, or an inability to activate postural adjustments in advance of potentially destabilizing voluntary movements.[9,10] For example, when lifting an object in front of the body, one must stabilize the body with key extensor musculature in advance of lifting or he or she will fall backward. Persons with neuromuscular problems like stroke and Parkinson disease are particularly prone to experiencing these deficits.

Since balance emerges from multiple systems, the underlying cause for one person's balance dysfunction can be dramatically different from the cause for another person. Therefore, each person must be examined for the specific cause of his or her balance problems and interventions should be tailored to address his or her specific needs.

Balance dysfunction results in a variety of mobility disorders; the most significant of which is falls. More than one-third of adults older than 65 years fall each year in the United States.[11,12] Among older adults, falls are the leading cause of injury and deaths and the most common cause of nonfatal injuries and hospital injuries for trauma.[13] In 2000, direct medical costs for fatal falls totaled \$179 million and \$19 billion for nonfatal injuries.[14] Even fallers who are not injured are likely to develop a fear of falling and may limit their activities resulting in reduced mobility and physical fitness, increasing their risks for future falls.[15] Consequently, balance dysfunction and falls are significant societal challenges resulting in great expense and human suffering.

Older adults can take several steps to reduce and/or prevent balance dysfunction and falls including reducing environmental hazards, adjusting medications (with appropriate medical supervision) to reduce negative side effects, and exercise. Aquatic therapy (AT) has been suggested as safe and effective approach to improving balance and postural control using a variety of hydrodynamic principles. The purpose of this article is to describe (1) the rationale for using AT for improving balance, (2) AT techniques that hold promise for improving balance, and (3) evidence supporting the use of AT for managing balance dysfunction. This discussion will address balance dysfunction caused by a variety of pathological conditions (eg, stroke, Parkinson disease, osteoporosis), as well as resulting from the normal aging process. The article will address AT interventions applied in the healthcare setting (eg, skilled rehabilitation) and in the community (eg, fitness programs).

## RATIONALE FOR USING AQUATIC THERAPY TO IMPROVE BALANCE

The physical properties of water, including buoyancy, turbulence, viscosity, hydrostatic pressure, and thermal influence, can be applied to the interventions directed at improving balance dysfunction.[15–18] In this section, each major system underlying balance control will be addressed in relation to how these physical properties of water can potentially be applied during AT activities. An indepth discussion of this topic is beyond the scope of this article. The scope of this chapter does not include a detailed explanation of these concepts. The reader should review additional resources and the summary provided in Table 1.

### Musculoskeletal systems

Buoyancy provides support to a client's body and allows for easy handling and positioning by the therapist so that a variety of passive stretching activities can be used to improve flexibility and joint ROM. This buoyant support also provides assistance to the client's active movements to promote active stretching for the same purposes. Muscle strengthening can be effectively achieved using a variety of water properties and therapeutic strategies. The graded assistance to active movement provided by buoyancy can be applied to strength training for individuals who are unable to perform such activities on land. Once stronger, the properties of turbulence and viscosity can be used to promote more vigorous isotonic strengthening to body parts moving through the water. Combined with the therapist's ability to support and position the client, this more vigorous resistance can be used for the dual purpose of facilitating movement patterns and strengthening body movements as is done during the Bad Ragaz

**Table 1.** Hydrodynamic principles and interaction with balance and postural control training

| Hydrodynamic principles | Balance and postural control training |
|---|---|
| Hydrostatic pressure | Assist with muscular contraction<br>Input into proprioceptors and joint mechanoreceptors<br>Equal resistance in all planes—ideal isokinetic "machine"<br>Diminish discomfort perception<br>Edema reduction systemically and locally (lymphedema, joint inflammation) |
| Buoyancy | Reduction in gravity allowing greater recruitment time, motor planning, integration of body awareness<br>Assistive or resistive force to assist with increasing range of motion, strengthening, endurance training, power activities |
| Viscosity: challenge to balance and postural control | Greater resistance than air dependent on rate of movement, surface area, length of lever arm |
| Turbulence: challenge to balance and postural control | Turbulent flow—competing currents<br>Laminar flow—same-direction currents |
| Temperature: facilitates or inhibits muscle tone | Cooler: stimulation to increase muscle readiness to work, decrease inflammation<br>Warmer: relaxation, tone reduction |

Ring Method (BRRM) (see the following text). Using the same properties described earlier, AT techniques can also be used to provide effective core strengthening that could potentially influence the client's ability to withstand perturbations from external forces. Viscosity can slow movements and allow a patient to adjust to perturbations before the client falls. This allows clients to perform activities that they would be fearful to try on land and could be applied to more aggressive movements like those used in power strength training (eg, vertical jumping, stepping onto a step).

### Sensory systems

A variety of sensory afferent systems can be activated using the physical properties of water. Buoyant support allows clients to assume upright postures for activation of joint receptors in the spine and lower extremities during functional training. Viscosity and turbulent drag can provide resistance to movements, which in turn stimulate muscle receptors. Hydrostatic pressure and turbulence can also stimulate cutaneous receptors. This can be enhanced by using jets of water or eddy currents. Finally, vestibular system input can be influenced by passive movements applied by the therapist (eg, *watsu*) or during the clients' functional activities (eg, water walking).

Another potential sensory-affecting tool, temperature, depends on the client's physiologic state.[19–21] If our client with reduced awareness of the body in space also displays decreased tone in trunk and extremity musculature, a cooler pool temperature could be used to increase tone. But if the client presents with increased tone that interferes with function, an initial *watsu* series in a warmer pool would be an effective use of temperature to assist in increasing functional abilities and decreasing tone. Nociception, autonomic response, and readiness to contract muscle tissue can all be directly affected by water temperature. Cooler water stimulates muscle readiness to work and decreases inflammation, whereas warmer water facilitates relaxation and tone reduction.

### Neuromuscular strategies

Muscle recruitment is enabled in the aquatic environment because the buoyant support of the water slows the movement and allows increased time for recruitment of an appropriate postural response. If an appropriate response is not produced, the buoyant support will assist to prevent a fall and potential injury. In addition, muscle timing is facilitated with the additional sensory cues provided by the water's viscosity. This increased ability to address timing of agonist and antagonist muscle firing makes the aquatic environment a positive venue in which to train people with neuromuscular difficulties.

Buoyancy provides a natural unloading to use body-weight-supported gait training. Currently, an increasing use of body-weight-supported treadmill training is employed to facilitate innate neuromuscular stepping strategies or central pattern generators.[22–25] The aquatic environment provides this unloading to facilitate stepping patterns without harness intrusion and allows movement in all planes with unloaded support. Practitioners vary the amount of unloading by altering the water depth for the needs of each client.

Turbulence can be used by the therapist to support patient's balance by assisting movements and/or by reducing the need for balance strategies. This is achieved by using a laminar flow or water currents moving in the same direction of the desired motion. Turbulence can also be used to challenge patients' balance, resist movement, and/or increase the need for postural strategies. This is achieved by using turbulent flow or water currents flowing in an opposing direction to the desired motion.

### Anticipatory mechanisms

One rehabilitation training category that is highly linked to the preceding neuromuscular strategies area is the support that the aquatic environment offers to clients who are addressing anticipatory mechanisms. Particularly for initial training in speed-amplitude relations for people with balance issues, the aquatic environment allows practice without the fear of falling. For example, in the water more time is available to practice BOS outside the center of gravity. Clients with anticipatory problems may not be able to adjust quickly to changes in environmental conditions like a spill on the floor or to reach outside the BOS to push an elevator button.

Challenging the patient to control balance and postural control by providing initial perturbations in an aquatic environment permits problem solving without a fall as a consequence. Of course, the caveat is that the client's position in the water must be gradually adjusted through increasingly shallow water and onto land while the client performs successful anticipatory motor planning. Alternatively, an accommodation can be made by widening the BOS with an assistive device. Step length and change of direction can also be practiced without fear of falling (because of buoyancy) in an aquatic environment.

## AQUATIC THERAPY INTERVENTION APPROACHES

A number of AT techniques have been described in the literature as positively influencing factors that contribute to balance control. In the following section, selected AT techniques will be described and their potential for managing balance dysfunction will be discussed.

### *Watsu*

Water shiatsu (*watsu*) was developed by Harold Dull at Harbin Hot Springs, California.[26,27] Dull describes the technique as Zen shiatsu principles applied to people floating in the water. *Watsu* was created as a wellness technique; it was not originally intended for patients with neuromuscular disorders. Rehabilitation practitioners apply the approach to patients with a variety of physical disorders, and reports indicate clinical success. On the basis of Eastern medicine theory, *watsu* stretches the body's meridians (pathways of energy). Rotational movements release blocked energy from soft tissue and joint articulations. In addition, these slow, rhythmical rotational movements reduce hypertonicity through tone-inhibiting vestibular stimulation. The stretches comprise specifically described transitions and sequences of movement including the basic moves, head cradle sequence, near leg over sequence, far leg over sequence, and the saddle sequence.[26,27]

The application of *watsu* to tight body segments can improve flexibility. Also, when applied using slow, rhythmic rotational movements, stimulation to the vestibular system sends inhibitory input down the lateral vestibulospinal tract of the spinal cord, resulting in full body relaxation and muscle tone reduction. This technique is particularly helpful when applied at the beginning of a treatment session, preparing the patient to move in a less restricted fashion during more active portions of the treatment session.

Examples of specific *watsu* maneuvers include near leg rotation (promoting internal and external hip rotation), the leg push (promoting hip extension), and the accordion (promoting hip and trunk flexion). These activities are particularly helpful for addressing certain musculoskeletal-related structural limitations (eg, range-of-motion limitations, hypertonic muscles) that lead to balance dysfunction. Theoretically, however, *watsu* could also have a positive influence on sensory integration disorders resulting from vestibular dysfunction by providing vestibular stimulation.

### *Ai chi*

*Ai chi* was developed by combining techniques from Eastern-based treatment approaches of tai chi, shiatsu, *watsu*, and Qi Gong and performing them in the water.[28] Flexibility and core (abdominal) strengthening are the most mentioned therapeutic benefits of *ai chi*. The approach is also said to promote relaxation from diaphragmatic (slow and deep) breathing that stimulates the parasympathetic nervous system, the portion of the nervous systems responsible for

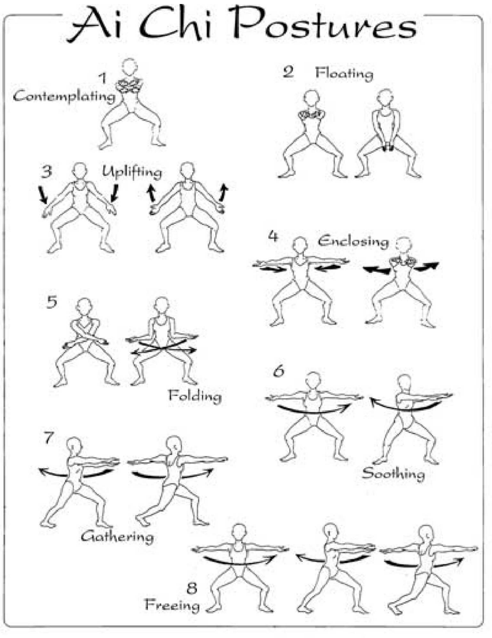


**Figure 2.** Typical sequence of *ai chi* postures.

calming effects (eg, reduced heart rate). Other therapeutic benefits include improved flexibility, ROM, balance coordination, general mobility, and mental alertness. *Ai chi* is performed in shoulder-depth water and incorporates deep breathing and slow, broad movements of the arms, legs, and torso. The approach follows a typical sequence of postures (see Fig 2 and progresses from simple breathing to incorporating movements of the upper extremities, then trunk, then lower extremities, and finally total body movements.

### Bad Ragaz Ring Method

The BRRM was developed in the 1930s in Bad Ragaz, Switzerland.[29,30] The technique developed through the years and was dramatically influenced by proprioceptive neuromuscular facilitation (PNF), a therapeutic exercise technique. Bad Ragaz Ring Method is similar to PNF in that the therapist guides the patient through specific patterns of movement to increase strength and ROM. Both techniques include passive or active movements for the arms, legs, and trunk and may use unilateral or bilateral patterns. Of the bilateral patterns, some are symmetric (both sides of the body moving in the same direction) and some are asymmetric (each side moving in a different direction).

In both BRRM and PNF, the therapist gives the patient specific movement instructions (eg, "bring your right knee to your left shoulder")and encourages a movement progression of distal to proximal segments of the body. In BRRM, the patient is floating either prone or supine in the water with flotation support at the neck, hips, and, for some unilateral tasks, the extremities. The therapist places his or her hands on designated spots on specific segments of the patient's body while instructing the patient to move in the desired direction. The therapist thus serves as a point of stability from which the patient moves, generating resistance from the turbulent drag effects of the surrounding water. Generally, resistance to movement is encountered in every direction of movement (ie, flexion and extension) because the body is completely surrounded by water.

Unlike PNF, in which the therapist manually applies graded resistance to the patient's movements, the BRRM allows the patient to determine the amount of resistance encountered on the basis of speed of movement and the resulting turbulent drag of the water. Using this method, therapists increase the difficulty of the activity by placing their stabilizing hold more distally. Such strategies do not necessarily increase the resistance to movement but do increase the complexity of the activity because the patient must control larger segments of his or her body during the movement. Only in a small portion of the patterns described, does the therapist use manual resistance to the patient's movement. At times, the therapist may use an overflow principle with the BRRM by stabilizing and resisting one portion of the body to encourage activity in another.

The BRRM was designed for a variety of movement problems, mainly muscle strength and active ROM. However, the technique can be effectively applied to the treatment of motor coordination impairments that include movement sequencing and scaling that are critical for the use of effective balance strategies. Like PNF, facilitation techniques are used to enhance movements (eg, quick stretch, timing for emphasis) by increasing the efficiency of the central nervous system with sensory input.

## Halliwick concept

Developed by James McMillan in the 1930s at the Halliwick School for Girls in England, the Halliwick method is based on principles of hydrodynamics and human development.[31–35] The original approach (Ten-Point Program) functioned as a swimming instruction technique, yet many of the Ten-Point Program activities and an elaboration of it (The Logical Approach to Exercise in Water) can be applied to specific therapeutic intervention. In general swimming instruction, each patient is assigned an individual instructor. This patient-instructor pair becomes one of a group of pairs, usually consisting of 4 to 6 pairs per group. Games are often used to teach skills and reinforce the principles of the method. In specific therapeutic intervention, however, activities are often conducted with each patient individually.

The Halliwick method, best described as a neurotherapeutic facilitation rehabilitation technique, follows a disengagement principle. Therapists or instructors use activities to facilitate patterns of movement with careful consideration of the activity's level of difficulty and the amount of manual guidance provided. Specifically, the therapist starts with easy activities and guides the patient manually to ensure correct execution of the movement. As the patient becomes more skilled with the movement, the therapist reduces the amount of assistance provided (disengaging) and increases the activity's level of difficulty. Activities are made more difficult by modifications in the patients' position and the therapists' handling techniques. Finally, when the patient masters the activity, the therapist creates turbulence around the patient's body to challenge skill and subsequently reinforce learning.

Using the Halliwick method for swimming instruction is ultimately therapeutic for all people because of the conditioning effects inherent in this form of exercise. It is particularly helpful for individuals with impairment and disability secondary to neuromuscular disorders. The approach can also be used to influence movement problems directly, for example, patients believed to be dominated by extensor movement patterns may benefit from gaining skill in vertical rotation control in an anterior direction. Such a movement helps the patient to actively control flexor musculature and inhibit extensor musculature. Skill gained through balance-in-stillness activities may carry over and influence postural stability during functional activities.

## Task-type training approach

A task-type training approach (TTTA) for aquatic rehabilitation is documented for patients who incur a stroke.[36–39] For this article, the guidelines and principles of the TTTA extend to the treatment of all patients with balance dysfunction. The TTTA can best be described as a task-oriented approach: Emphasis is placed on influencing the patient's disability by working in functional positions with functional activities. In addition, patients are encouraged to become active problem solvers of their movement difficulties as opposed to passive recipients of manual and verbal input from practitioners. Notably, the TTTA is not a treatment technique but a set of principles to guide therapists in designing treatment programs for their patients. The general principles are as follows:

1. *Work in most shallow water tolerated.* The buoyant support of the water allows patients to stand independently and move in a functional manner for the first time. Patients can actively and aggressively work to improve their skill with functional tasks.

The ultimate goal is for the functional improvement to carry over to gravity-influenced land activities; therefore, the effect of buoyant support should be systematically removed as patients demonstrate skill with functional activities. Performance indicators, such as the inability to maintain an erect trunk while standing or the inability to maintain knee extension in supporting lower extremities, may show that deeper water is better for functional activity practice.

2. *Practice functional activities as a whole.* Although some treatment programs address strengthening or stretching of specific body segments or facilitating specific movement patterns, the TTTA encourages practice of activities that are identical to or closely approximate the land functional activities to be improved. This principle is based on a specificity-of-training principle that a functional skill requires practice to be learned.[40] When performed as a whole, the entire functional skill must be mastered, including control of moving body segments and appropriately graded contraction of stabilizing body segments.
3. *Systematically remove external stabilization from patients.* Holding onto the pool wall or the therapist's manual assistance may be necessary in the earlier stages of a TTTA. This externally applied stabilization should be quickly removed as patients gain independent control over the functional activity. Thus, the therapist minimizes the patient's dependence on outside support for functional skills.
4. *Encourage stabilizing contractions in upright positions with movement of selected body segments.* Vertical or upright positions (ie, sitting, standing) are positions of function and should be used as much as possible. Stereotypical strategies for maintaining postural stability in upright positions are identified. Patients with neuromuscular disorders typically demonstrate difficulty using these strategies to maintain their balance, so they are encouraged to relearn these maneuvers in a safe but challenging environment, the water. As patients move their extremities in or above the water, their center of balance is challenged. Prevention of falling requires use of effective postural stability strategies. The patient is forced to solve problems actively to redevelop these strategies, with attention given to contracting the appropriate muscles, in the proper sequence, and with the appropriate force of contraction.
5. *Encourage quick, reciprocal movement.* Many functional activities require rhythmic, reciprocal movements along with quick movement changes to maximize the use of inertial forces. Movement in this manner ensures smooth and efficient execution of functional activities. Weakness, ROM limitations, and other voluntary movement deficits prevent patients with balance dysfunction from moving effectively in a gravity environment; the supportive and assistive properties of water dramatically increase the likelihood of their doing so. Therefore, whenever possible, quick, reciprocal movements should be practiced (eg, marching in place, pedaling the legs while supine). Such practice may produce a conditioning effect that will positively influence the impairments that constrain patients with neuromuscular disorders to slow, labored movements.
6. *Encourage active movement problem solving.* Motor learning research suggests that healthy humans learn movement skills better when they actively participate in the learning process.[41] For example, when subjects are given less feedback on their performance and are required to practice many and

varied activities, they must become more reliant on their own ability to critique and modify their performance, leading to more active participation. Studies of patients with neuromuscular disorders have come to similar conclusions. For this reason, patients should be encouraged to critique their performance and propose movement solutions to their problems. Open-ended questions, such as "How did you do that time?" and "How can you improve your next attempt?" should be used whenever possible. When working with patients with neuromuscular disorders in the pool, several factors may make the use of such principles difficult. Many patients with neuromuscular disorders have difficulty critiquing their performance because of physical (ie, sensory) and cognitive (ie, perceptual) impairments. In this case, the therapist must provide minimal guiding feedback regarding the patient's performance.

7. *Gradually increase the difficulty of the task.* Task characteristics can be modified to increase or decrease the challenge of a functional activity. Gentile provides a taxonomy to describe task characteristics that make a task more or less difficult.[42] For example, introducing intertrial variability to a task, or changing task requirements from trial to trial, increases the skill required to execute the task. A therapist could use this strategy when performing balance training with a patient. While passing a ball with a patient attempting to remain standing, the therapist could throw the ball to the same spot, with the same speed and at the same time (no intertrial variability). Conversely, the task could be made more challenging by varying the speed, timing, and location (with intertrial variability).

Another variable that could be altered within the taxonomy is the use of body stability activities (eg, the patient is not required to move from one location) or body transport activities (eg, the patient is required to move from one location to another during the task execution). Using such a progression with balance training, the patient would pass the ball from one location. Later, the patient would pass the ball while walking forward. Table 2 includes examples of specific AT activities that are in line with the TTTA principles.

**Table 2.** Task-type training approach activities commonly used to improve gait dysfunction

*Standing weight shift*. Client stands and shifts weight from one leg to the other. Slight knee flexion should occur in the unweighted lower limb.

*One leg up*. Client stands facing the pool wall and lifts 1 leg repeatedly. Emphasis is placed on active hip flexion and passive knee flexion.

*Marching*. Client lifts and lowers one leg, followed immediately by the same on the other leg. Speed and coordination are emphasized.

*Kick back*. Client stands facing the pool wall and kicks 1 leg in a posterior direction repeatedly. Emphasis is placed on hip extension with knee extension.

*Side kick*. Client stands facing the pool wall and kicks 1 leg to the side repeatedly. Emphasis is placed on hip abduction and knee extension.

*Straight leg kick*. Client stands with side to the pool wall and swings 1 leg forward and back repeatedly. Emphasis is placed on hip flexion and extension, with knee extension on the swinging lower limb and hip and knee extension on the stance limb.

*Walking with front support*. Therapist stands in front of the client and provides bilateral support to the client's upper limbs.

*Walking with side support*. Therapist stands at the client's side and provides unilateral support to one of the client's upper limbs.

## EVIDENCE FOR USE OF AQUATIC THERAPY FOR IMPROVING BALANCE

A growing number of publications have described AT interventions to manage balance dysfunction. In this section, these reports will be considered in chronological order.

Taylor and colleagues[43] used a single-case ABAB study design to examine the effects of an AT program on gait parameters for 2 individuals in the chronic phase of recovery from stroke. The B (treatment) phases of the study included 25 minutes of water walking, 3 days each week for 3 weeks in each phase. Participants walked continuously during each session and were verbally encouraged to normalize their gait symmetry. Short rest breaks (generally less than 2 minutes) were provided every 10 minutes and participants' heart rate was monitored to ensure that they safely achieved the defined intensity level. The gait parameters examined were velocity, cadence, and stride length. Results were examined using visual analysis of celeration lines and a 2 standard deviation band (2SDB) method; both commonly used methods of analysis for single-case design studies. Participant 1 exhibited significant improvements for all 3 gait parameters using the 2SDB method, and visual analysis suggested improvement for cadence only. Participant 2 exhibited a significant improvement in cadence using visual analysis and the 2SDB method and a trend toward improvement using visual analysis for velocity and stride. The authors concluded that the AT program consisting of water walking did produce positive effects on selected gait parameters for both participants. Of note, both participants were relatively young (33 and 55 years of age) and both entered the study with fairly good gait skills. Therefore, there may have been a ceiling effect–influencing outcome. Also, the authors noted the limitations of making generalizations from single-case design studies.

Ruoti et al[44] examined the influence of an organized nonswimming aquatic exercise class on a variety of physical parameters in older adults (age 50–75 years). In their study, 12 participants were assigned to participate in an aquatic exercise program lasting 60 minutes, 3 times each week for 12 weeks. Eight individuals were assigned to a no treatment control group. The water exercisers' protocol consisted of a variety of trunk and lower extremity strengthening activities and aerobic conditioning. All participants were tested 3 times each week regarding resting heart rate, maximum heart rate, maximum oxygen consumption ($\dot{V}O_{2max}$), body composition, and muscular endurance as assessed by work capacity in the water. The water exercise group improved significantly on all measures except body composition, whereas the control group experienced no significant changes. The investigators concluded that nonswimming water exercise was effective for improving cardiorespiratory fitness and work capacity in older adults. Of most significance to this topic of balance control are the improvements observed for work capacity or muscular endurance.

Morris et al[45] reported findings from an ABAB single-case design study exploring the use of an AT program for improving gait and balance with 3 older adults (61–75 years old) in the chronic phase of recovery from stroke (more than 6 months). All participants were independent with gait but all typically used a straight cane, and 2 of the 3 participants used an ankle foot orthosis. Outcome measures included the functional reach (FR) test and gait parameters including velocity, cadence, stride length, and single limb stance on left and right legs. Results were analyzed using visual analysis and the 2SDB method described by Taylor et al.[43] An AT program was conducted for 3 weeks during the first treatment phase and for 6 weeks during the second treatment phase. The treatment sessions lasted for 45 minutes, 2 times a week, and included 5 minutes of warm-up, 10 minutes of active stretching of key lower extremity muscle groups, 15 minutes of movement control activities (eg, water walking and marching with a target heart rate of 70% of the participants/maximum heart rate), 5 minutes of cool down, and 10 more minutes of active lower extremity stretching. Results revealed an improvement in FR as assessed by visual analysis but not from the 2SDB method. Gait analysis demonstrated positive results also, yet different participants experienced benefits for different gait parameters. The authors concluded that the AT program showed promise for improving gait and balance in older adults recovering from stroke. However, they noted that data collection difficulties and the limitations of generalizing single-case design results should be considered before drawing conclusions from this investigation.

A 1996 report by Taunton et al,[46] compared a generalized water exercise program to a land-based exercise program for improving cardiorespiratory fitness, body composition, forward trunk flexion, and strength in older women (between 65 and 75 years of age). Forty-one healthy, sedentary older women were randomly assigned to either the water or land-based exercise groups; each exercising 45 minutes per session, 3 times each week for 12 weeks. Outcome measures were performed prior to the treatment period, during treatment, and after treatment and included measures of peak aerobic power (oxygen consumption per unit time [$\dot{V}O_2$] peak), forward trunk flexion, sum of skin folds, grip strength, curl-ups and push-ups. Results revealed that both groups experienced significant improvements in $\dot{V}O_2$ peak with no significant difference between the groups. The land-based group also demonstrated significant improvements in the total number of curl-ups. The investigators concluded that both exercise protocols were equally effective in improving cardiorespiratory fitness but not specific enough to lead to improvements in muscular strength, flexibility, or body composition.

Simmons and Hansen[47] examined the effects of water exercise on postural mobility in the healthy older adults. Fifty-two independently living adults were recruited from a residential retirement community. They were assigned to 1 of the following 4 groups: (1) water exercisers, (2) land exercisers, (3) water sitters who sat in the water without exercise but with supervised socialization, and (4) land sitters who participated in supervised socialization activities on land. All groups met separately twice a week for 5 weeks. The exercises used in the water and land exercise groups consisted of gait, balance, and lower body strengthening activities. Outcomes were assessed using the FR test weekly during the entire intervention. At the beginning of the trial, each group was at risk for falling (FR $< 10$ in). The water exercise group significantly increased their FR scores every week of the intervention period to a final FR score of $13.4 \pm 16$. The land exercisers significantly increased their FR scores during the first week only for a final FR score of $11.3 \pm 1.5$. The water- and land-sitter groups did not increase their FR scores at all during the intervention period and remained in the "at risk for falling" score range. The authors hypothesized that exercise in water provided more opportunities for challenging balance and that participants were more comfortable with vigorously engaging in higher-level skills, resulting in greater improvements in balance.

In 2000, Suomi and Koceja[48] examined the effects of an AT on postural sway for women with lower extremity osteoarthritis or rheumatoid arthritis.[48] Twenty-four older adult women were recruited to participate in an AT program designed to improve strength, ROM, and mobility for persons with arthritis. Eleven of the participants were diagnosed with rheumatoid arthritis and 13 were diagnosed with osteoarthritis. The exercise group met 3 times a week for 6 weeks and exercised for 45 minutes each session. Ten individuals with arthritis were enrolled in a no treatment control group. The primary outcome measure was postural sway as assessed by the 2-legged stance test. Aquatic therapy exercise group members experienced significant reductions in postural sway and control group members experienced no changes. On the basis of their findings, the authors concluded that the AT program was beneficial for improving balance control in persons with arthritis.

Douris and colleagues[49] examined differences in the effectiveness of land- and water-based exercises for improving balance. Eleven older adults were enrolled as participants. Five participants were recruited from an assisted living facility and performed lower body exercises on land. Six participants were recruited from an outpatient physical therapy clinic and performed lower body exercises in the water. Both groups participated in 2 exercise sessions each week for 6 weeks. The Berg Balance Scale (BBS) was administered at pre- and posttreatment time intervals. As evidenced by posttreatment BBS scores, both groups experienced statistically significant improvements in balance. There was not a significant difference in change scores between groups however. The authors concluded that use of land- or water-based exercises was equally effective in improving balance in older adults. They cited a low sample size and the lack of randomization as significant limitations to their study.

Devereux and colleagues[50] examined the effects of a water-based exercise and self-management program on balance, fear of falling, and quality of life in community-dwelling women 65 years and older with a diagnosis of osteopenia or osteoporosis. Participants included 50 women who were randomized into an intervention or a control group. The intervention group participated in a 10-week water exercise class, 2 times weekly. The exercise sessions lasted 50 minutes and exercises were described as warm-up, stretching, aerobic, strengthening, and activities to improve posture, gait, vestibular function and proprioceptive function. Tai chi activities were also included. Members of the intervention group also participated in brief self-management educational sessions addressing such topics as medications, footwear and falls risks, and hazards. Participants in the control group did not participate in any educational sessions and were not encouraged to change their physical activity, activities of daily living, or social habits during the study. Outcome measures included the step test, the Short Form-36 questionnaire (SF-36), and the modified Falls Efficacy Scale. Results demonstrated significant improvements in the step test and physical function, vitality, social function, and mental health domains of the SF-36. There were no significant differences in pre- to posttreatment changes scores on the Falls Efficacy Scale for either group. The investigators concluded that the intervention was effective for improving balance and quality of life in older adults but not reducing fear of falling.

In 2006, Lord et al,[51] published a report of a study conducted to examine the influence of a 22-week AT program for improving physical functioning in older adults. Eighty-five participants were recruited to participate in the "Waves" group AT program for 1 hour each week for two 10-week sessions; with a 2-week break between sessions. The AT program included activities designed to improve participants' muscle strength, muscle power, coordination, and agility. Forty-four individuals were assigned to a control group and received no intervention during the study period. Outcome measures included maximal lean in anterior and posterior directions, coordinated stability, shoulder ROM, quadriceps strength, and reaction time. Only forty-eight participants completed the entire program; 37 participants dropped out. The AT group demonstrated significant improvements in maximal lean ability, coordinated stability, and shoulder ROM but not in quadriceps strength or reaction time. The control group did not experience changes in any outcome measure. The authors noted that other investigators had found significant strength changes in comparable groups of participants. They theorized that the infrequent number of exercise sessions in their study (ie, only 1 time each week) may have been insufficient to produce strength changes.

Tsourlou and colleagues[52] published a report of their examination of the effects of a 24-week AT program on muscle strength, flexibility, and functional mobility in healthy women older than 60 years. Twenty-two participants were randomly assigned to an AT group ($n = 12$) or control group ($n = 10$). Members of the AT group exercised for 60 minutes, 3 days each week during the study period. The AT protocol consisted of aerobic and resistance components including 10 minutes of warm-up and stretching, 25 minutes of endurance activities with a target of 80% of heart rate maximum, 20 minutes of upper and lower body resistance exercises with specialized equipment, and 5 minutes of cool down. Outcome measures included knee flexor and extensor isometric strength (assessed using a dynamometer), grip strength, and 3 repetition maximum for chest press, knee extension, latissimus dorsi muscle pulldown, and leg press. Body composition was measured using bioelectrical impedance testing, jumping performance was evaluated using the squat jump and flexibility in trunk flexion as assessed by the sit-and-reach test. Finally, functional mobility was assessed using the timed up-and-go test. Participants in the AT program demonstrated significant improvements in all outcome measures, whereas the control group experienced no significant changes in any outcome measure. A unique aspect of this study was use of heart rate monitors during the entire AT session to ensure appropriate exercise intensity. The investigators also used music to guide participants to move at a certain speed and modified the exercise program with increased music tempo as the weeks of training progressed.

Roller et al,[53] examined the influence of a water-based exercise program conducted at YMCA for improving Berg Balance Test scores for women older than 65 years. Thirteen women, all residents of assisted living facilities, participated in the water exercise program for 45 minutes, 2 times weekly for 6 weeks. The program was conducted in shallow water; was supervised by a personal trainer; and included active ROM exercises, water walking, and using water weights for strengthening. Results revealed that Berg Balance Test scores improved significantly from pre- to posttreatment. The authors concluded that the water exercise program was effective for improving balance in older adult women. They also recommended that the protocol be compared to a land-based exercise program.

Melzer and colleagues[54] are currently investigating a water-based program including specific perturbation exercises that target the stepping response that could potentially have a positive effect in reducing falls. The proposed water-based training program involves use of unpredictable multidirectional perturbations that evoke compensatory and volitional stepping responses. Concurrent cognitive tasks during movement tasks are included and principles of physical training and exercise include awareness, continuity, motivation, overload, periodicity, progression, and specificity. The protocol is being studied in a prospective randomized, cross-over trial with 36 community-dwelling older adults. Voluntary step reaction times and postural stability using stabilogram diffusion analysis are being used as outcome measures.

Noh and colleagues[55] conducted a randomized controlled trial to evaluate the effect of an aquatic exercise protocol designed to improve balance in persons with stroke. The twenty-five participants were in the chronic phase of recovery from stroke (more than 6 months) and could walk independently with or without an assistive device. They were assigned to receive the aquatic intervention or a conventional, land-based exercise program. All interventions were conducted for 1 hour, 3 times a week for 8 weeks. The AT program was based on principles of the Halliwick and *ai chi* methods. Two participants were supervised by 1 therapist at each session and sessions included 10 minutes of warm-up activities, 20 minutes of Halliwick method activities, 20 minutes of *ai chi* method activities, and 10 minutes of cool down activities. Primary outcome measures were the BBS and weight-bearing abilities as measured by vertical ground reaction force during 4 standing tasks. Secondary measures included the Modified Motor Assessment Scale and muscle strength of knee and back musculature. The participants in the aquatic exercise group demonstrated significantly better improvements in the BBS, forward and backward weight-bearing abilities, and knee flexor strength than participants in the control group. There were no significant differences in the other measures between the groups. The authors concluded that the aquatic interventions were effective in improving balance in persons in the chronic phase of recovery from stroke.

Gabilan and colleagues[56] examined the therapeutic effects of aquatic exercise for persons with unilateral vestibular hypofunction (UVH). Twenty-one persons with chronic dizziness (more than 3 months) from UVH were recruited to engage in 10 treatment sessions of 45 minutes each for 3 times each week. The exercise program consisted of 12 phases and was based on specialized techniques consistent with the Halliwick method and BRRM. The treatment protocol also incorporated vestibular rehabilitation principles of adaptation and substitution mechanisms targeting eye-head movements and coordination of sensorimotor strategies and active body control alignment. Participants were progressed through the stages on the basis of their responses to the maneuvers and the complexity of the exercises. Outcome measures employed included the Dizziness Handicap Inventory, Dynamic Computerized Posturography, and the Self-Perception Scale of Dizziness. All outcome measures revealed statistically significant improvements following the intervention. There was no association between age, time since symptom onset, and use of antivertigo medication. The authors concluded that the intervention was effective in reducing physical effects of UVH regardless of age, chronicity, and use of medication.

## SUMMARY

Balance dysfunction can result from the negative effects of the aging process on musculoskeletal factors, sensory capabilities, postural strategies, and/or anticipatory control skills. These problems can be compounded by medical conditions commonly experienced by aging adults (eg, stroke, Parkinson disease, osteoporosis). The physical principles of water allow the application of a wide range of therapeutic strategies to positively influence balance control. Mounting evidence suggests that AT is beneficial, when applied as part of rehabilitation and/or community fitness programs, for improving balance control.

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