Review

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The glamor of and insights regarding hydrotherapy, from simple immersion to advanced computer-assisted exercises: A narrative review

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SUMMARY Water-based therapy has been gaining attention in recent years and is being widely used in clinical settings. Hydrotherapy is the most important area of water-based therapy, and it has distinct advantages and characteristics compared to conventional land-based exercises. Several new techniques and pieces of equipment are currently emerging with advances in computer technologies. However, comprehensive reviews of hydrotherapy are insufficient. Hence, this study reviewed the *status quo,* mechanisms, adverse events and contraindications, and future prospects of the use of hydrotherapy. This study aims to comprehensively review the latest information regarding the application of hydrotherapy to musculoskeletal diseases, neurological diseases, and COVID-19. We have attempted to provide a "take-home message" regarding the clinical applications and mechanisms of hydrotherapy based on the latest evidence available.

Keywords water-based therapy; hydrotherapy; rehabilitation; neurorehabilitation; musculoskeletal diseases

1. Introduction

Water-based therapy, also referred to as "spa therapy," is akin to land-based therapy and includes a spectrum of potentially efficacious modalities using water or mud. Water-based therapy, which usually includes hydrotherapy, aqua therapy, and balneotherapy, is commonly used along with other therapies, including land-based exercises and massage, in clinical practice. Hydrotherapy, also termed "aquatic therapy," is an important area of water-based rehabilitation. It was started by Charles Leroy Lowman in 1911, who used therapeutic tubs to treat patients with spasticity, and is widely used for rehabilitation purposes (*1*). Contrary to land-based exercises, movement in water is influenced by the physical properties of water, such as density, specific gravity, hydrostatic pressure, buoyancy, viscosity, and thermodynamics, and hence is associated with special effects. The main advantages of hydrotherapy are: *i)* it provides a safer exercise environment than land-based therapies because of the lower risk of falls (*2*). Because of the low psychological burden of falling, patients can focus on exercise, thereby enhancing the effects of balance and stability training. *ii)* Owing to the buoyant nature of water, the burden of body weight on the joints of the lower limbs is alleviated, thereby reducing the strain on the knees, ankles, and hips (*3*). Appropriate training, including range of motion in these joints, gentle strength building, and gait training, can have a better efficacy. *iii)* Movement in water requires the person to overcome water resistance, which increases the effort associated with exercise. Therefore, exercises such as deep-water running might be more efficacious than those performed on land (*3*). Hydrotherapy enhances respiratory and cardiopulmonary functions because of the hydrostatic pressure exerted on the thorax (*4*). *iv)* Stimuli associated with water *per se*, including water temperature and flow, may contribute to the effects of physical therapy. *v)* Community-based hydrotherapy encourages patients. For example, the mandatory communication required during hydrotherapy can benefit children with communication disorders. Communicating with the coach, therapist, or other patients might potentially benefit children with autism (*5*). For individuals who have difficulty walking, a lower risk of falls (compared to land-based walking exercises) may enhance their self-confidence. A well-organized hydrotherapy course is helpful to encourage individuals to build momentum and keep training. In addition to conventional athletic rehabilitation (*6,7*) and neurorehabilitation (*8*), hydrotherapy is widely used to relieve pain associated with labor (*9,10*) and a battery of diseases including knee osteoarthritis (KOA) (*2*), vascular diseases (*11,12*), pediatric disorders (*13,14*), chronic diseases such as hypertension (*15*), obesity and type 2 diabetes (*16*), and chronic obstructive pulmonary disease (*4,17*). Due to its characteristics, hydrotherapy can be used in several situations: *i)* For older adults with balance problems because of the lower associated risk of falls. A systematic review by Shariat *et al*. included 385 participants in 15 trials to investigate the efficacy of hydrotherapy in improving balance in older adults (*18*). They concluded that hydrotherapy had a positive impact on dynamic balance in the elderly population. *ii)* For obese patients with disorders of the lower joints, the buoyancy of water can relieve the burden on the knees, ankles, and hips. Lim *et al*. conducted a randomized controlled trial (RCT) to compare the efficacy of aquatic exercise and land-based exercise in treating obesity in obese patients with KOA, and they reported that aquatic exercise was more efficacious in reducing body fat since the patients could exercise more due to less pain (*19*). *iii)* For children, since most children enjoy playing in water. Lai *et al*. evaluated the efficacy of hydrotherapy in children with cerebral palsy and found that children undergoing pediatric aquatic therapy had better Physical Activity Enjoyment Scale scores compared to the control group post-treatment (*20*).

Several insightful reviews have discussed the applications and mechanisms of hydrotherapy from various perspectives. Becker summarized the marked physiologic changes associated with hydrotherapy as well as its clinical applications in rehabilitation in 2009 (*1*). Later, in 2020, Becker further summarized the applications of hydrotherapy in neurological diseases (*8*). These two articles are landmark papers on hydrotherapy. Torres-Ronda *et al*. reviewed the properties of water and their applications in training (*21*). They focused on the muscle damage and soreness following exercise in athletes. Mooventhan and Nivethitha reviewed the impacts of hydrotherapy on various physical systems (*22*). This was the first review to comprehensively summarize the application of hydrotherapy to the whole body. In addition, several systematic reviews have evaluated the efficacy and safety of hydrotherapy in different diseases. Bartels *et al*. reported small, short-term, and clinically relevant effects of hydrotherapy on OA-related pain, disability, and quality of life (QOL) in patients with knee and hip OA (*23,24*). Reger *et al*. conducted a review that investigated the effectiveness of hydrotherapy in treating cancer, but they failed to reach a concrete conclusion because of the heterogeneous results (*25*). These reviews have provided useful insights regarding the clinical use of hydrotherapy from different perspectives. Hydrotherapy is commonly practiced in clinical settings, but the comprehensive reviews are limited and hydrotherapy-related mechanisms in particular are still not completely understood. Hence, the aim of the current review was to present updated information related to hydrotherapy. We have attempted to provide "take-home messages" regarding the clinical applications and mechanisms of hydrotherapy based on the latest evidence available.

2. The underlying mechanisms of hydrotherapy

Mechanisms of hydrotherapy are not yet completely understood. The temperature of water is known to play a vital role in terms of those mechanisms. Different water temperatures can trigger different physiological reactions (*22*). Cold water centralizes the circulating blood to perfuse major organs, which can help reduce lymphedema and heal chronic wounds with analgesic and antiphlogistic effects (*25*). Warm water induces vasodilation, which can relieve vascular spasm and relax muscles. Warm water also relieves hypertension and chronic pain. Thus, cold water immersion (CWI), warm water immersion, and contrast water therapy are selected based on different clinical scenarios and seasons (Table 1). Whole-body cryotherapy (WBC), namely short exposure (2–4 min) to very cold air (−100°C, −150°F) has been reported to ameliorate muscle soreness (*26*) and muscle pain (*27*) due to harsh training through alleviation of systemic inflammation and repair of muscle damage. A study by Driller and Leabeater has demonstrated that the recovery effects of CWI are comparable to those of WBC; however, CWI can more easily conducted (*7*). A study focusing on balneotherapy reported that balneotherapy might reduce several proinflammatory cytokines such as TNF-α and IL-1β and increase anti-inflammatory molecules such as IGF-1 growth factor particularly in musculoskeletal diseases (*28*). Thus, anti-inflammatory action might be regarded as a significant mechanism of hydrotherapy.

Currently, neurotransmitter-related mechanisms of hydrotherapy are attracting attention (*29*). Peripheric serotonin levels are thought to be associated with a spectrum of neuromuscular diseases *via* development and resolution of immunity/inflammation-related mechanisms (*29*). However, a series of experiments by an Italian laboratory found no significant differences in 5-HT platelet transporter levels in participants who had undergone thermal balneotherapy (*30,31*). The dopaminergic pathway has been found to be involved in the pathophysiology of OA, and a dysfunction in systemic or local dopaminergic system has been found to be associated with several inflammatory diseases. Some researchers have hypothesized that immunomodulation of dopamine might contribute to the mechanisms by which spa therapy treats OA (*29*). However, only one study in Japan reported enhanced serum dopamine levels in healthy participants after a 15-minute hydrotherapy session (*32*).

Table 1. Selection of an appropriate temperature protocol for hydrotherapy

Items	Cold water	Warm water	Alternating between warm and cold water
Commonly used protocol	Cold water immersion	Warm water immersion	Contrast water therapy
Recommended temperature	11–15°C (50–59 °F)	38–40°C (100–104 °F)	Alternating between cold and warm
Duration	11–15 min	≥10 min	≥10 min
Physiological reactions	Increases: Activity of the sympathetic nervous system metabolic rate, heart rate, systolic blood pressure and diastolic blood pressure, plasma noradrenaline and dopamine, diuresis Decreases: Plasma cortisol renin levels	Opposite effects of cold water in the column on the left	Depends on the duration of warm/cold immersion
Physiological effects	Increases: Local anesthetic effects Decreases: Local metabolic rate and edema, nerve conduction velocity, muscle blood flow, and muscle spasm	Opposite effects of cold water in the column on the left	Depends on the duration of warm/cold immersion
Clinical applications	Muscle fatigue and soreness, chronic wounds	For relaxation	Used as an acute post-exercise recovery strategy

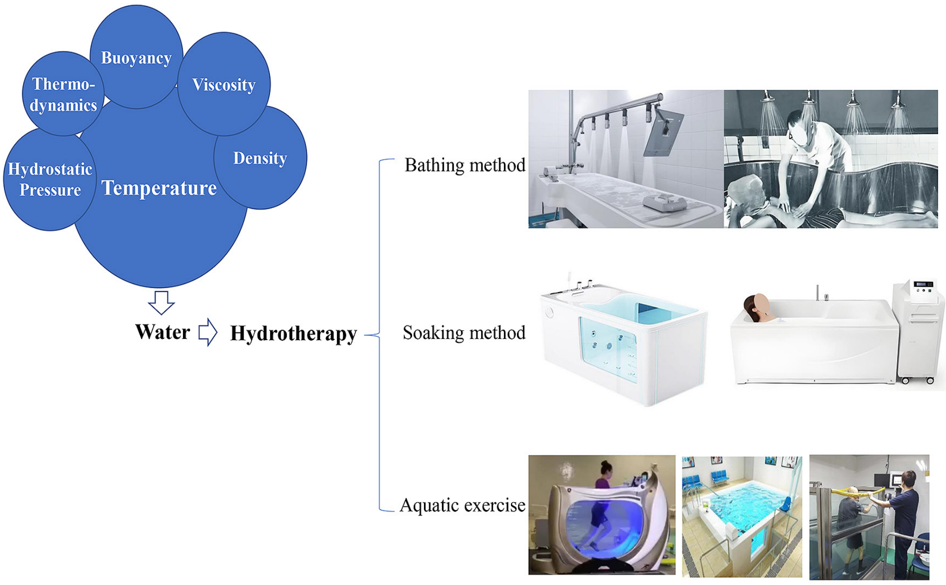

Figure 1. Methods based on treatment modalities used in hydrotherapy.

Overall, evidence concerning mechanisms of hydrotherapy is insufficient and further study is warranted.

3. Modality

Based on treatment modalities, hydrotherapy can be categorized into bathing methods, soaking methods, and aquatic exercise therapy. In brief, bathing methods are similar to a shower and refer to slowly streaming water that is maintained at an appropriate temperature over the body or using a water jet with appropriate pressure to vertically stream water over body parts. Bathing methods differ from the common shower since parameters such as water temperature and pressure can be controlled. Soaking methods use soaking equipment such as a bathtub. Either the full body or part of the body is immersed in water at certain temperatures and the water might be medicated. Aquatic exercise therapy refers to conducting exercise therapy in an aquatic environment (Figure 1).

Techniques for hydrotherapy can include either a conventional approach or special techniques. Conventional approaches refer to conducting conventional land-based exercise in an aquatic environment, such as a pool or a special tank (Figure 1). Special techniques include several approaches specifically developed for hydrotherapy, such as Ai Chi (*1*), the Halliwick method (*33*), the Bad Ragaz Ring therapy (*34*), and WATSU (WaterShiatsu) (*35*). These approaches should be selected after considering the pathophysiology and the goals of rehabilitation. For example, the Halliwick method is particularly recommended for patients with physical or learning difficulties (*33*). These individuals are trained to engage in water activities, moving and swimming independently in water. The main techniques commonly used in hydrotherapy are listed in Table 2.

4. Clinical applications of hydrotherapy

The most common application of hydrotherapy is for sports-related rehabilitation or post-exercise recovery among athletes (*21,36*). However, considering the aim of this review, we shall focus on the clinical applications of

Table 2. Commonly used hydrotherapy techniques and their applications

Methods	Advantages	Weaknesses	Applications
Conventional approaches			
Aquatic obstacle training	Mainly trains the initiation of movement; good for gesture failure and freezing of gait in patients with PD.	Only suitable for patients with mild-moderate PD (Hoehn & Yahr stage 2−3); Requires certain walking ability; Involves a risk of falls.	PD, Stroke.
Aquatic treadmill	Safe and easy to use; Can be used to evaluate multiple functions simultaneously.	Requires expensive equipment, has modest efficacy compared to other training programs.	Athletic rehabilitation, obesity, PD, SCI, Stroke.
YMCA arthritis	Improvement of stability and compensatory effects.	Only suitable for females.	Arthritis.
Group warm water therapies, Aqua aerobics, Water yoga	Good for improvement of communication between patients and boosting self-confidence of patients.	In terms of compliance, males and younger people are worse compared to females and older people.	Arthritis, ASD, neuromuscular disease, obesity.
Deep-water running, Aqua jogging	Interesting; Good for improvement of cardiopulmonary function and regional cerebral blood flow.	Involves a risk of falls, not good for improvement of cognitive function.	Inactive elderly people, obesity, arthritis.
Dual-task training	Good for training the motor cortex and basal ganglia; helpful for formulating a walking training strategy, training for body coordination and motor execution.	Requires a certain level of ability to walk independently; modest improvement of cognitive function.	PD, stroke.
Special techniques			
Ai Chi	Interesting, and readily accepted by most patients; Allows training in static and dynamic balance simultaneously; Good for training if respiratory function is good.	Only suitable for patients with a certain level of balance (score greater than 3 on Item 2 of the Berg Balance Scale). Very deep-water is risky.	Arthritis, PD, spine and fracture.
Halliwick	Interesting, and readily accepted by most patients; One-on-one training format; Balance and independence are taught.	Mainly used for children; Certain levels of understanding and communication are required.	ASD, CP, MS, PD, Stroke.
Bad Ragaz Ring method	May result in a satisfactory efficacy when combined with proprioceptive neuromuscular facilitation exercises.	Commonly used for early rehabilitation.	Arthritis, Chronic low back pain, Stroke.
WATSU	Uses the meridian and acupoint theory of traditional Chinese medicine; Can provide physical and spiritual relaxation; marked alleviation of pain.	Efficacy is markedly affected by water temperature; passive rehabilitation; patients cannot gain full activity.	ASD, FS, MS, neuromuscular disease, PD, obesity.

ASD: autism spectrum disorder, Ai Chi: Taichi in the water, CP: cerebral palsy, FS: fibromyalgia syndrome, MS: multiple sclerosis, PD: Parkinson's disease, SCI: spinal cord injury, WATSU: WaterShiatsu, pressure finger massage in the water, YMCA: Young Men's Christian Association.

hydrotherapy for rehabilitation of patients with various diseases.

4.1. Musculoskeletal diseases

Over the past few decades, mounting evidence supports the contention that hydrotherapy is beneficial at improving the symptoms of musculoskeletal diseases such as OA (*29,37,38*), fibromyalgia (*39-43*), inflammatory arthritis (*44*), exercise-induced muscle damage (*45*), juvenile idiopathic arthritis (JIA) (*46*), ankylosing spondylitis (AS) (*47,48*), low back pain (LBP) (*49,50*), and musculoskeletal pain (*51,52*). Hydrotherapy also relieves musculoskeletal pain associated with hemophilia (*53,54*), and helps in recovery after joint surgery (*55,56*). Primary benefits of hydrotherapy include: *i)* redistribution and enhancement of the blood supply along with the oxygen supply of the musculoskeletal system; *ii)* alleviation of pain, since pain is the main symptom associated with several musculoskeletal diseases such as KOA (*57*); *iii)* relief of an inflammatory reaction. Several studies have reported that hydrotherapy can reduce proinflammatory cytokines and increase anti-inflammatory cytokines (*28,58*); *iv)* suppression of the activity of the sympathetic nervous system by reducing noradrenaline levels and blocking nociceptors (*58*).

4.1.1. Osteoarthritis

Lower limb osteoarthritis (OA), and KOA in particular, is a very prevalent condition since the joints of the lower limb are complex and vulnerable. Hydrotherapy plays an important role as a part of comprehensive OA treatments (*59*). Several previous studies have documented the efficacy of hydrotherapy in treating KOA. A meta-analysis by Dong *et al*. compared the efficacy of hydrotherapy to that of land-based exercises in treating KOA (*60*). They reported that there were no significant differences in the efficacy of hydrotherapy and land-based exercise in terms of pain relief, physical function, and QOL. Better compliance and levels of satisfaction were observed with hydrotherapy; however, it was found to have modest efficacy at improving the activities of daily living (ADL). Another study found that hydrotherapy was effective at alleviating pain and improving physical function, muscle strength of knee extension, and walking ability in individuals with KOA (*61*). A recent study that used Bad Ragaz Ring therapy in hot spring water to treat KOA reported that the Western Ontario and McMaster Universities OA index scores were better for the hydrotherapy group in terms of pain, stiffness, and function (*62*). Duan *et al*. reported that hydrotherapy might have only a short-term efficacy in treating OA-related pain, physical function, stiffness and athletic ability that did not persist as of a long-term follow-up (*63*). Another study conducted on women suffering from KOA in Europe yielded different results. According to that study, intensive aquatic resistance training program only resulted in a mild short-term amelioration of knee stiffness but no short- or long-term amelioration of pain, physical function, or QOL (*64*). A plausible interpretation of the heterogeneity of the aforementioned studies might be the variations in the recruiting of patients, treatment conditions, and small sample sizes. Well-designed, large, and multicenter RCTs can provide more robust evidence regarding the efficacy of hydrotherapy in treating OA.

4.1.2. Fibromyalgia

Fibromyalgia is another well-documented musculoskeletal disease that is treated with hydrotherapy. Fibromyalgia is associated with hyperalgesia and deficient pain inhibition that might be induced by hyperactivity of the hypothalamic–pituitary–adrenal axis and dysfunction of dopamine (*65*). Hong-Baik *et al*. found that elevated levels of proinflammatory cytokines such as IL-1β, IL-6, IL-8, and TNF-α in patients with fibromyalgia were reduced by hydrotherapy (*58*). Hence, they concluded that low chronic inflammation might contribute to the mechanisms of fibromyalgia and might be alleviated by hydrotherapy. Although the definition and classification of and the diagnostic criteria for fibromyalgia remain controversial, "relief of pain" is the main consideration in treating patients suspected to be suffering from fibromyalgia. Hydrotherapy is therefore considered and used to treat fibromyalgia. Hydrotherapy might modulate the hyperactive hypothalamic–pituitary–adrenal axis, activate the thermal receptors and mechanoreceptors, and suppress the nociceptors, helping to alleviate pain (*66*) and thereby ameliorate related symptoms such as sleep disturbance (*40*). Ai Chi has been reported to be the most effective method of treating fibromyalgia, and particularly for improvement of sleep quality (*40*). Earlier in 2009, Calandre *et al*. compared the efficacy of Ai Chi and stretching and found that Ai Chi significantly alleviated fibromyalgia-related symptoms and improved sleep quality while stretching only ameliorated the psychological well-being of the enrolled patients (*67*). A recent study has confirmed the efficacy of hydrotherapy in improving sleep quality, alleviating pain, and improving QOL in patients with fibromyalgia (*40*). Two studies that compared the efficacy and safety of hydrotherapy to land-based exercise for fibromyalgia have reported similar results, and they found hydrotherapy to be superior to land-based exercise, in terms of both pain control and improvement of sleep quality (*41,68*). In addition, social pressure is closely associated with fibromyalgia (*69*), and its prevalence is higher in females (*70*). Hydrotherapy is reportedly useful at reducing social pressure and improving muscle strength (at least 20%) and functional capacity in women (*71-73*). However, hydrotherapy has not been found to be superior to other treatments like mat Pilates (*74*) and a health education program (*75*) in female patients with fibromyalgia. Nevertheless, hydrotherapy remains a valuable treatment modality for alleviating the symptoms of fibromyalgia.

4.1.3. Fracture

Hydrotherapy is commonly used for the post-surgical rehabilitation of fractures and is used during both fixation as well as during convalescence. Deep-water running (DWR) has recently gained popularity for rehabilitation of fractures and osteoporosis in the lower limbs. When patients are training in a pool with 70% of their body immersed in water, submerged at shoulder level, and feet touching the pool bottom, the buoyancy of the water reduces the vertical ground reaction forces, thereby diminishing joint load and minimizing the potential risk of injury to the musculoskeletal system (*76*). Open-chain movement, which cannot be performed on land, is possible in an aquatic environment. DWR enables patients to exercise more. It also enables more complicated movements and a wider range of movements. Moreover, DWR is effective at maintaining cardiorespiratory function (*76*). In addition, DWR reduces the patients' fear of falling and enables them to experience the feeling of accomplishment.

Hydrotherapy activates bone formation biomarkers, suppresses bone resorption biomarkers, and improves bone metabolism, facilitating bone calcification and reconstruction (*77*). Exercise in water has been found to stimulate neuromuscular excitability, establish synaptic links, enhance nerve innervation rate, and restore muscle strength and muscle tone (*78*). In addition, hydrotherapy helps to reduce the likelihood of fragility fractures in the elderly by improving bone density and gait stability (*79,80*). Taken together, hydrotherapy can confer neuromuscular, psychological, and cardiorespiratory benefits that are recommended for patients with fractures, and elderly patients with osteoporosis-related fractures in particular.

4.1.4. Anterior cruciate ligament injury

Anterior cruciate ligament (ACL) injury is not rare among basketball and football players who usually indulge in rotating, variable, and opposing motions. ACL injury markedly affects the competitive level of athletes. Only 65% athletes have been reported to return to the same competitive level after undergoing ACL reconstruction surgery (*81,82*). Thus, selection of a worthwhile rehabilitation protocol that can rapidly restore knee joint function and minimize movement limitations is inevitable but challenging. Hydrotherapy plays a unique role in the rehabilitation of an ACL injury (*83*). Again, thanks to the property of buoyancy, water helps to reduce the weight-bearing load for patients undergoing post-surgical rehabilitation of an ACL injury. Pressure exerted on the knee joints can be adjusted by changing the level of immersion. With immersion to the neck, pressure on the knee is approximately 15 pounds, while immersion up to the symphysis pubis, umbilical region, and xiphoid regions results in knee pressure that is approximately 60%, 50%, and 40% of body weight, respectively (*1*). Water temperature is beneficial for producing and recruiting motor units. Hydrostatic pressure may alleviate tissue edema by promoting venous and lymphatic return (*84*). In the event of sudden onset pain, the drag force and turbulence of water can promptly decelerate limb movement, thereby reducing the risk of a repeat injury due to fall in comparison to exercise on land. The aquatic environment helps patients to maintain their balance by reducing the proprioceptive deficit in the flexion of the knee. Moreover, hydrotherapy helps to enhance the strength of the quadriceps and hamstring muscles, leading to a substantial reduction in reliance on the unaffected leg (*85*). A hybrid rehabilitation protocol that includes gymnasium, aquatic, and field exercises was reported to be helpful at enabling athletes to return to competition following rehabilitation for 90 days (*86*). Hajouj *et al*. found that alternately walking forward and backward on a foam roll in a pool promoted neuromuscular coordination and proprioception efficiency, helping after ACL reconstruction (*87*). So *et al*. reported on the significance of an aquatic treadmill (ATM) after ACL reconstruction (*88*). When participants ran at a cadence of 110 steps per minute, there was marked neuromuscular activation of the biceps femoris muscle in the stance phase and rectus femoris in the swing phase, potentially improving knee stability and protecting the ACL. Moreover, an increase in the depth of water was accompanied by a corresponding increase in muscle activity. All of this evidence supports the contention that hydrotherapy can yield positive outcomes in rehabilitation of an ACL injury. Selection of an appropriate rehabilitation protocol with appropriate use of auxiliary equipment, such as a foam roller and ATM, might play a crucial role in achieving satisfactory efficacy following an ACL injury.

4.2. Neurological diseases

Neurorehabilitation is also an important area of modern rehabilitation medicine. Hydrotherapy is widely used in the rehabilitation of neurological diseases such as stroke (*89-99*), Parkinson's disease (PD) (*100*), multiple sclerosis (MS) (*101-103*), and dementia in adults, along with cerebral palsy (CP) (*14*) and autism spectrum disorder (ASD) (*5*) in children. Other than these widely reported diseases, hydrotherapy is also mentioned for treatment of conditions like migraines (*104*) and Rett syndrome (*105*). Hydrotherapy usually is performed as a part of the rehabilitation protocol, and it might have better efficacy when combined with conventional physiotherapy. Moritz *et al*. reported that a combination of hydrotherapy and physiotherapy might be useful at overcoming activity limitations in stroke, but not in PD and other neurological diseases (*106*). In terms of the direct influence of hydrotherapy on the central nervous system (CNS), no new findings other than those from Becker were available, according to whom: *i)* hydrotherapy can increase regional cerebral blood flow (rCBF) due to enhanced cardiac output; and *ii)* hydrotherapy positively impacts the autonomic nervous system in a significant manner, including suppression of sympathetic activity and maintenance of sympathovagal balance (*8*). The complex neural mechanisms impacted by hydrotherapy warrant further study.

4.2.1. Stroke

Stroke is the second leading cause of death and the third leading cause of disability (*107*). Post-stroke rehabilitation is known to markedly improve the clinical outcomes of stroke (*108*). To achieve a satisfactory clinical outcome including good ADL, QOL, and the ability to return to the community, a proper post-stroke rehabilitation plan that provides early, active, and sustained intensive training is indispensable. Hydrotherapy is no exception. Apart from conventional land-based post-stroke rehabilitation, hydrotherapy offers added advantages. Like conventional land-based rehabilitation, hydrotherapy provides motor and sensory stimuli, induces neuronal plasticity, and improves motor function along with static and dynamic balance in individuals suffering from a stroke (*109*). Therefore, hydrotherapy has been widely used as an adjuvant therapy in clinical settings. Hydrotherapy constitutes a coherent rehabilitation protocol for stroke patients combined with conventional rehabilitation methods since mounting evidence has shown that use of hydrotherapy in combination with other rehabilitation methods results in better rehabilitation than use of hydrotherapy alone (*106*).

Hemiplegia is the most predominant neurological deficit in stroke patients. Hence, overcoming hemiplegia is the first crucial task for both land- and water-based rehabilitation modalities. Cronin *et al*. evaluated the efficacy of hydrotherapy in reducing hyperreflexia in seven stroke patients with hemiplegia, and they found that water immersion for a short amount of time (5 min, 33℃) significantly reduced peripheral reflex excitability in patients as well as in healthy controls (*110*). Reduction of hyperreflexia in hemiplegic limbs is significant for post-stroke rehabilitation. Cronin *et al*. speculated that immersion for a longer amount of time might be required to have a persistent effect. Hence, water immersion is recommended for rehabilitation in hemiplegic stroke patients. Bei *et al*. compared the effects of hydrotherapy in combination with conventional post-stroke rehabilitation on the recovery of lower limb dysfunction in hemiplegic patients suffering from a first stroke (*89*). They found that early aquatic exercise results in better balance, walking performance, and limb coordination (*vs.* conventional rehabilitation). Special equipment specially developed for hemiplegic patients is required for hydrotherapy with better efficacy. Pereira *et al*. developed special buoyancy cuffs for aquatic exercise used in post-stroke patients with hemiplegia (*96*). This equipment was found to modify gait kinematics, which might be play a positive role in aquatic exercise training.

The most commonly used hydrotherapy method in post-stroke rehabilitation is aquatic exercise training involving active therapeutic movement, which is known to improve the functions of the lower limbs. Mounting evidence indicates that ATM facilitates enhanced balance, muscle strength and function of the lower limbs, and cardiopulmonary function (*8*). Saleh *et al*. conducted an RCT to compare the effects of rehabilitation using ATM and conventional land-based training on balance and gait in patients with chronic stroke, and they found that ATM improved isometric paretic knee flexor and knee extensor strength (*111*). ATM training was found to have better efficacy at improving balance and gait functions in these patients. Later, a study involving subacute stroke patients by Lee *et al*. compared the results of ATM and conventional land-based training (*112*). They found that ATM improved maximal isometric strength in the knee flexors and extensors (*vs.* land-based training) and concluded that ATM improved isometric muscle strength in the lower limbs. As with the application of ATM to other diseases, the important parameters are water temperature, water depth, walking speed, and duration. Parfitt *et al*. investigated the effects of ATM using different parameters, and they found that rCBF and heart rate (HR) improved with a longer time and faster speed on the treadmill (*113*). The ATM group had greater improvement of rCBF and a lower overall HR (*vs.* land-based training). Deeper water immersion may further lower the HR. Parfitt *et al*. concluded that ATM led to greater rCBF improvement, which contributed to optimizing the shear stress-mediated adaptation of the cerebrovasculature. Besides ATM, other hydrotherapy methods such as Ai Chi and Halliwick have also been used for post-stroke rehabilitation. A series of RCTs by Sagrario and Cruz compared the efficacy of Ai Chi to land-based rehabilitation and the combined use of Ai Chi and land-based rehabilitation (*114-116*). They found that Ai Chi and the combination group had better pain relief and amelioration of dysfunctions of balance (static and dynamic) and gait. These improvements contributed to a better QOL. The group receiving combination treatment had more improvement. Importantly, Rafsten *et al*. pointed out that Ai Chi helped to improve self-confidence and resilience and ameliorate post-stroke depression (*117*). Zhang *et al*. reported that the combination of the Halliwick method and ATM had better efficacy (*vs.* land-based rehabilitation) in terms of increasing muscle strength and ameliorating muscle co-contraction without increasing spasticity in patients with subacute stroke (*118*). The aforementioned evidence demonstrates that hydrotherapy is an effective option for post-stroke rehabilitation, although a combination of hydrotherapy and conventional land-based rehabilitation might result in better efficacy.

4.2.2. PD

PD is the second leading neurodegenerative disease (NDD) and has been a global concern. Patients with PD commonly suffer from motor and non-motor symptoms that markedly impact their daily life. Early and timely rehabilitation can significantly improve the ADL and QOL of patients with PD (*119*). Considering the pathophysiological characters of PD, several issues should be taken into account when devising a rehabilitation protocol for a patient with PD: *i)* patients with advanced PD commonly suffer from bradykinesia, gesture failure, and freezing of gait (FOG). Balance disturbance is common in patients with PD, so these patients have a greater risk of falls compared to healthy individuals. *ii)* Due to rigidity and bradykinesia, patients with PD find performing certain exercises more strenuous and they have less stamina in rehabilitation training. *iii)* Non-motor symptoms, such as cognitive impairments, mood dysfunction, and weaker executive function, can reduce their compliance with and adherence to the rehabilitation plan. *iv)* Due to the progressive nature of PD, the rehabilitation protocol needs to be adjusted in a timely manner depending on the patient's status and treatments (medication and/or surgery). Hence, as with the selection of a proper assessment task, the principles of objectification, multi-purpose, and simplification (OMS) as proposed in our previous studies (*119-121*) are also appropriate for the selection/development of a rehabilitation method for patients with PD. Moreover, the development of rehabilitation methods, and particularly for patients with PD, is highly encouraged and practiced (*119-121*). Hydrotherapy is recommended for PD rehabilitation due to the lower risk of falls and satisfactory efficacy in improving lower limb strength, balance, and gait. However, there are some specific concerns to consider once hydrotherapy is selected for PD rehabilitation: *i)* Water temperature: Currently, heat shock protein (HSP)-related PD mechanisms have garnered a great deal of attention. HSPs are known to be associated with the restoration of damaged proteins, response to inflammation, and tissue injury (*122,123*). Immersion in warm water can raise the core body temperature and act on HSPs, thereby relieving PD-related symptoms (*124*). Thus, selection of warm water is reasonable. However, higher pool temperatures (≥33℃) should be used with caution, since warmer water might be appropriate only for low-intensity training or for patients with advanced PD and reduced physical capacity. *ii)* Location of hydrotherapy training: Carroll *et al*. reported that patients with PD may benefit from community-based hydrotherapy due to the timely provision of information and encouragement of adherence (*125*). Access to a rehabilitation location is an important factor due to the physical restrictions on patients with PD. A feasible location might improve the adherence of patients with PD to sustained long-term rehabilitation. *iii)* Long-term program: Hydrotherapy should be regularly and consistently performed due to the progressive and lifelong nature of PD. Bloem *et al*. recommended that hydrotherapy should be performed for at least 12 weeks, twice a week, and for 30–60 minutes at a time as a long-term course (*126*). *iv)* Protection: Considering the compromised movement of patients with PD, hydrotherapy for patients with PD requires more caution and protection by the therapist or coach. *v)* Individuation: The complex nature of PD symptoms leads to several individual differences among patients. Thus, the rehabilitation protocol should be individually selected depending on the pathophysiological status of the given patient. The main training components should seek to attain the goals of rehabilitation for the patient, and factors such as locomotion performance (*127,128*), gait (*127,129*), trunk stabilization and rotation (*128*), balance (*127-130*), and QOL (*128*) should be considered.

Several hydrotherapy methods have been used for PD rehabilitation. Conventional hydrotherapy methods like Ai Chi and Halliwick have been reportedly used in PD rehabilitation. Kurt *et al*. reported that Ai Chi improved balance, mobility, motor ability, and QOL in patients with PD (*128*). Moreover, Ai Chi had a better efficacy compared to land-based rehabilitation in patients suffering from mild to moderate stages of PD. In a pilot study, Terrens *et al*. reported that Halliwick alleviated balance dysfunction in patients with PD, and they recommended Halliwick as a safe treatment for patients with PD (*130*). Furthermore, several rehabilitation tasks originally performed on land were modified to be performed in water. Dual-task aquatic training is used for comprehensive training of patients with PD. Performing dual-task training in water may improve walking capacity and lead to better body adjustments and better motor skills, along with a reduced risk of falls. An RCT by da Silva and Israel compared the efficacy of dual-task aquatic training to a control group (not exercising), and they found that patients undergoing dual-task aquatic training had better functional mobility, gait, and balance (*127*). Recently, the same group investigated the efficiency of dual-task aquatic training in improving the motor symptoms, ADL, and QOL in patients with PD. They found that dual-task aquatic training can improve motor functions and ADL; however, a combination of aquatic and land-based dual-task training was recommended (*131*). Aquatic obstacle training (AOT) is developed for treating FOG. FOG is a common symptom in advanced PD, which is closely associated with the risk of falls and QOL. Hydrotherapy is frequently recommended for rehabilitation of patients with FOG, because an aquatic environment can provide substantial stimuli for both central sensorimotor integration and peripheral muscle activity (*132*). Zhu *et al*. conducted an RCT to compare the efficacy of rehabilitation of AOT and Halliwick method in patients with PD and FOG (*129*). They found that after 6 weeks of training, AOT had a better efficacy with regards to gait and balance than the Halliwick method in these patients. However, another study found no significant differences in outcomes of motor-cognitive rehabilitation between land-based training and land-based training + hydrotherapy in patients with PD and FOG (*133*). The study therefore concluded that hydrotherapy was not associated with more benefits for motor-cognitive rehabilitation. A recent study designed a sequential multimodal rehabilitation protocol, namely sequentially performing water- and land- based exercises for 12 weeks, for patients with PD (*134*). The study found that this multimodal protocol markedly improved balance, ADL, and motor functions in these patients. Moreover, hydrotherapy and land-based rehabilitation are complementary therapies, and their combination might result in better efficacy. Sleep disturbance is an important non-motor symptom in PD (*135*). Loureiro *et al*. conducted an RCT comparing the efficacy of PD rehabilitation using conventional land-based training and land-based training + WATSU (*136*). They found that land-based training + WATSU had better efficacy in improving sleep quality and QOL in patients with PD.

4.2.3. MS

MS is a chronic progressive demyelinating disease involving the CNS. MS-related symptoms involve a spectrum of neurologic deficits, involving cognitive impairments, fatigue, symptoms of cranial nerve palsy (diplopia, visual field deficits, dysphonia, and dysphagia, *etc*.), paresthesia, dysfunctions of gait and balance, ataxia, spasticity, walking disorder, and bowel and bladder disorders. Mental and mood disorders are not rare. The ADL and QOL of patients are markedly influenced by these complex and individual symptoms. However, there is currently no specific treatment or definitive cure for MS. Other than medication, neurorehabilitation plays a significant role in the treatment of MS, and exercise training is the most effective non-pharmacological treatment for MS (*103*). The goals of rehabilitation include alleviation of functional disorders and improvement of ADL and QOL. All forms of physiotherapy, namely exercise rehabilitation, kinesiotherapy, massage, and certainly hydrotherapy, can be used for rehabilitation of MS. Mechanisms involved in MS rehabilitation are not completely understood. According to the literature, the neurorehabilitation-related mechanisms offer: *i)* Benefits of neuroplasticity: Bonzano *et al*. found that appropriate rehabilitation including voluntary movement of the upper limbs resulted in changes in the white matter microstructure and improved motor performance in patients with MS (*137*). In a resting-state functional nuclear magnetic resonance imaging (fMRI) study, Pareto *et al*. found that effective cognitive rehabilitation could lead to improved patterns of brain synchronization and resting-state networks along with amelioration of cognitive function in patients with MS (*138*). Bahmani *et al*. had reported that effective hydrotherapy could enhance neurotransmitter levels (*139*). In a review, Shariat *et al*. reported that an imbalance in brain-derived neurotrophic factor (BDNF) played a role in the pathophysiology of MS (*140*). Hydrotherapy could alleviate MS-related fatigue by elevating BDNF levels. Evidence from the aforementioned research indicates that effective neurorehabilitation exercise may have positive effects on the brain and alleviate neurological deficits. *ii)* Modulation of the peripheral and CNS immunomodulatory responses: A study by Souza *et al*. found that effective exercise suppressed the production of proinflammatory cytokines and upregulated regulatory T cell markers in spleen cells. Moreover, exercise reduced the permeability of the blood-brain barrier and limited the transmigration of autoreactive T cells to the CNS in animal models of autoimmune encephalomyelitis (*141*). In addition, exercise reportedly affected remyelination, neuroinflammation, microglia, astrocytes, and infiltrating immune cells in MS (*142*). MS is an autoimmune inflammatory disease, so the mechanisms of neurorehabilitation might be affected by protective regulation of the inflammatory response. *iii)* Regulation of the dysbiosis of the gut microbiota: Barone *et al*. reported that neurorehabilitation caused the modulation of the MS-related dysbiosis of gut microbiota by supplementing beneficial short-chain fatty acid producers and suppressing pathobionts (*143*). The study noted, along with improvement of physical performance and alleviation of fatigue, a reduction in proinflammatory lymphocytes, inflammatory markers (such as proinflammatory IL-17), and circulating lipopolysaccharide levels.

As rehabilitation treatment for MS, hydrotherapy has been used for management of fatigue (*140,144,145*), balance (*140,145*), spasticity (*144,146*), and QOL (*144,147*). Hydrotherapy has been recommended for relieving spasticity in MS since it can suppress the activity of gamma neurons, inhibit afferent impulses, and have relaxing and analgesic effects (*101*). A study by Amedoro *et al*. indicated that a combination of hydrotherapy and conventional land-based physical therapy may have a better efficacy in MS rehabilitation (*102*). Shariat *et al*. conducted a systematic review and found that hydrotherapy is effective at relieving fatigue and improving balance in patients with MS (*140*). Bahmani *et al*. found that hydrotherapy is helpful at improving sexual function in women with MS (*139*). Gurpinar. *et al*. compared the efficacy of hydrotherapy in the form of Halliwick and aquatic plyometric exercise (APE) in patients with MS. They noted significant improvement in the limits of stability and hand dexterity in both groups; however, the Halliwick method had better efficacy in terms of hand dexterity and overall limits of stability (*vs*. APE). Both Halliwick and APE are recommended for MS rehabilitation because of their safety and efficacy (*148*). A RCT involving women with MS concluded that hydrotherapy significantly improved functional capacity, balance, and fatigue in those subjects (*145*). All of these previous studies verified the value of hydrotherapy in MS rehabilitation. Hao *et al*. compared the effects of seven different exercise modalities (hydrotherapy, aerobic exercise, yoga, Pilates, virtual reality (VR) exercise, whole-body vibration exercise, and resistance exercise) on balance function and functional walking ability in patients with MS (*149*). They reported that hydrotherapy significantly reduced the Timed-Up-and-Go Scores, indicating a significant improvement in functional walking ability. The authors contended that hydrotherapy is superior to conventional land-based exercise and might be the best method to improve functional walking ability in patients with MS.

4.2.4. Dementia

Dementia has become a major public health concern with the aging of the global population. Age-related frailty is closely associated with various physiological or pathophysiological changes, including age-related hearing loss (*150*), accumulation of pathogenetic proteins like β-amyloid (Aβ) (*151*), and α-synuclein (*152*), dysbiosis of gut microbiota (*153*), and dementia (*150*). Alzheimer's disease (AD), the leading NDD, is the most common type of dementia (*154*). Thus far, there is no specific medication to cure dementia or even to reverse its progression (*155*). Several studies have confirmed the positive effects of aerobic activities performed on land as well as in the water on the improvement of cognition function (*156,157*), even in subjects with AD (*156*); nonetheless, the benefits that rehabilitation has on dementia, and particularly on mild cognitive impairment (MCI) and early dementia, remains controversial. Tortora *et al*. conducted a dementia-specific rehabilitation program focusing on strength, balance, physical activity, and ADL involving 365 patients with early dementia or MCI, but they noted no improvement in terms of ADL, physical activity, or QOL (*158*). According to a recent study by Antonenko *et al*., cognitive training with concurrent brain stimulation did not ameliorate symptoms in patients with cognitive impairments (*159*). In contrast, several recent studies reported that VR-based cognitive rehabilitation was effective at treating patients with MCI (*158,160*). The available evidence regarding hydrotherapy is insufficient. Kim *et al*. found that both hydrotherapy and land-based exercise increased serum Aβ and HSP27 and decreased pulse wave velocity in 40 older healthy women (*161*). Their results provided a working basis of hydrotherapy's potential to prevent NDDs. Becker and Lynch reported the first case of a 54-year woman with advanced AD who underwent 17 hydrotherapy sessions in 19 weeks (1 hour per day) in a warm water therapy pool, following which, her cognitive functions improved (*162*). A subsequent review by Becker mentioned the application of hydrotherapy to dementia, but no robust evidence was provided (*8*). Henwood *et al*. conducted an aquatic exercise program for residential aged adults with dementia for 12 weeks (*163*). They noted significant improvements in the skeletal muscle index and lean mass, but dementia-related behavioral and psychological symptoms and ADL only tended to improve ($p = 0.06$).

Overall, studies verifying the efficacy of hydrotherapy in treating dementia are insufficient, which might be due to the difficulties associated with conducting such studies. Medical personnel are usually reluctant to provide hydrotherapy to patients with cognitive impairments since it is risky and laborious. The study by Becker required two persons. Moreover, a situation in which patients cannot clearly communicate with the staff might result in a failure to identify a potentially dangerous situation in a timely manner. In addition, difficulty in accessing the hydrotherapy location, and/or poor economic conditions may curtail hydrotherapy for subjects with dementia. Nonetheless, studies verifying the efficacy and safety of hydrotherapy in treating dementia are warranted.

4.2.5. CP

CP is the most common lifelong movement disability in children (*164*), and it markedly influences the ADL and QOL of children. It is not progressive but improvement is rare in clinical practice. CP mainly affects gross motor skills, walking ability, spasticity, gait and balance, and it leads to compromised cardiorespiratory function, particularly in children, due to the lack of exercise. Mounting evidence indicates that CP-related symptoms can be markedly alleviated by rehabilitation exercises. Accordingly, children and adults (children who have grown up with CP) require regular rehabilitation (*165*), which involves therapeutic training including land-based exercises, muscle strengthening, stretching, balance training, task-oriented functional training, and hydrotherapy (*166*). Over the past 20 years, hydrotherapy has been used for CP rehabilitation (*8*). The physical properties of water, such as buoyancy and its comfortable temperature, can confer several benefits and allow many difficult tasks to be attempted. Immersion in warm water at 33℃–35℃ can reduce spasticity in children with CP (*167*). Moreover, exercise in water is interesting and relaxing for many children (children like to play in water) (*167*). Hence, hydrotherapy is readily accepted by children and parents.

In contrast to conventional land-based rehabilitation, hydrotherapy has the following advantages: *i)* Hydrotherapy is effective at improving gross motor skills. Akinola *et al*. conducted a 10-week hydrotherapy program involving 30 children with spastic CP who were divided into a hydrotherapy group and a control group. Both groups performed stretching and functional training exercise. The control group performed rehabilitation on land while the hydrotherapy group performed exercises in the water (28°C–32°C). After the intervention (10 weeks, twice per week), all domains of gross motor skills except walking, running, and jumping had significantly improved in the hydrotherapy group, and results for the hydrotherapy group were considered to be significantly better than those for the control group (*164*). Treatments like swimming (*168*) and the ten-point Halliwick program (*14,169,170*) are commonly used for CP rehabilitation and have demonstrated good efficacy at improving gross motor skills. *ii)* Hydrotherapy is useful at managing spasticity. Adar *et al*. compared the efficacy of hydrotherapy and land-based exercises in 32 children with CP (*168*). The hydrotherapy program included aquatic exercises (33°C, 60 min, five times per week for six weeks) and aerobic exercises (slow walking or swimming, 25 min). The study found that hydrotherapy had the same efficacy as land-based exercise for spasticity management and improvement of motor dysfunction. Hydrotherapy resulted in a better QOL. A Pakistan-based study also found that hydrotherapy in a pool (32°C–34°C, twice a week, 32 weeks) resulted in amelioration of spasticity and improvement in gross motor skills in children with CP (*171*). *iii)* Hydrotherapy helps to enhance cardiorespiratory function. Due to the hydrostatic pressure in an aquatic environment, fluids are driven from the extremities toward the central cavity, which results in the compression of the thorax, an increase in the respiratory load, and ultimately results in a subsequent increase (approximately 30%–60%) in cardiac output (*172,173*). Thus, hydrotherapy offers significant benefits in terms of enhancing cardiopulmonary function. This is especially beneficial for children with CP, who have compromised cardiorespiratory function due to lack of exercise. *iv)* Other than physical benefits, hydrotherapy can result in psychological improvements. Hydrotherapy is interesting and relaxing; this is helpful at relieving stress regarding the disease and training for children and parents. Moreover, exercise in the water allows the children to try difficult movements that cannot otherwise be performed on land, which has a positive influence on their self-confidence. Communication in the swimming pool with the therapist/coach or wardmates positively impacts their psychological states. Other than these advantages, a handful of studies have reported that hydrotherapy was efficacious at improving aerobic capacity (*174*), body fat, core strength, and bone mineral density (*175*).

However, the available research on CP-related hydrotherapy has several limitations that prevent the obtaining of more robust evidence. Most of the aforementioned studies were conducted using small sample sizes. In addition, important domains, such as CP-related pain, were seldom mentioned. Immersion in hot water is known to be helpful at relieving pain in infants (*176*). Hydrotherapy is also suitable for the management of chronic pain in patients with CP (*177*). However, no study has evaluated hydrotherapy's feasibility at alleviating CP-related pain thus far. Studies addressing these issues are highly anticipated.

4.2.6. ASD

ASD refers to a spectrum of genovariation-based neurodevelopmental disorders characterized by impairments in social communication, limited interests, and repetitive stereotyped behaviors. Barriers in social communication might prevent patients with ASD from participating in sports and exercises, thereby reducing their athletic activities. Conversely, motor impairments can cause problems in social communication, thereby forming a vicious circle (*178*). Previous evidence had indicated that improvement in motor ability *via* exercise interventions not only improved motor outcomes but also reduced impairments in behavior, cognition, and deficits in social communication (*178*). The mechanisms for this are not completely understood. Breaking the vicious circle involving motor impairment and deficits in social communication might be a plausible explanation. Based on this "vicious circle" theory, the application of hydrotherapy to ASD could confer two benefits: *i)* Direct effects by ameliorating behaviors as a direct result of hydrotherapy itself. Exercise or immersion in warm water is comfortable and enjoyable for most children. Hydrotherapy is helpful at reducing their stress and nervousness. Hydrotherapy can create opportunities for communication, such as inevitable communication with the therapist/coach and communication with other children undergoing training. Moreover, children with ASD reportedly need strong sensory stimulation. Exercise in the water involves a response to water pressure, and this strong sensory stimulation might result in a "calming effect," thereby improving their capacity to interact and communicate with other people (*179*). *ii)* Indirect effects involve the improvement of their motor skills, which might indirectly benefit their social communication. In addition, children with ASD usually suffer from sleep disturbance, which might be associated with elevated levels of circulating IL-1β and TNF-α (*180*). Hydrotherapy can reduce serum IL-1β and TNF-α levels, improving sleep quality (*181*). Sourvinos *et al*. reported that hydrotherapy is effective at improving language skills in children with ASD (*182*).

Thus far, the hydrotherapy programs for ASD, such as the Halliwick method, sensory exposure, iCan Swim, multi-systemic aquatic therapy (CI-MAT), and aquatic versus kata techniques training, are based on "learn-to-swim programs." The Halliwick method plays a crucial role among the aforementioned methods. The Halliwick method has benefits with regards to social communication and behavior in children with ASD. Moreover, these improvements might be further reinforced by communication with fellow trainees or with therapists (*183*). In addition to social communication, Vodakova *et al*. found that the Halliwick method was effective at improving gross motor skills (*33*). Thus, hydrotherapy, and particularly the Halliwick method, is beneficial for ASD rehabilitation.

4.3. COVID-19

Over four years have passed since the start of the COVID-19 pandemic. The dangers of the SARS-CoV-2 virus cannot be neglected (*184*). Indeed, numerous people are suffering from the post-acute sequelae of COVID-19, which are referred to as long COVID (*185*). Hence, the "application of hydrotherapy to COVID-19" is a topic that should not be ignored Bailly *et al*. reviewed the potential and feasibility of providing hydrotherapy during the COVID-19 pandemic (*186*). Antonelli and Donelli discussed the possibility of performing respiratory rehabilitation for post-COVID-19 patients in a spa center (*187*). A study pointed out that water from a swimming pool is not good for the survival of SARS-CoV-2 virus (*188*). A research protocol focusing on verification of the efficacy of hydrotherapy for post-COVID-19 children has been published (*189*). Lucas *et al*. reported a strategy to perform hydrotherapy during the pandemic (*190*). However, there are few studies that involved actually performing hydrotherapy during the pandemic, which might be attributed to measures such as "lockdowns" and "isolation at home" that were enforced to prevent the epidemic. Moreover, medical staff might be reluctant to conduct these rehabilitation training exercises for fear of being infected themselves.

All of the available studies are related to long COVID. Grishechkina *et al*. reported on the efficacy of a tailored and multidisciplinary rehabilitative program including hydrotherapy in treating patients with long COVID. Neuromotor rehabilitation consisting of aquatic exercises for muscle strength and balance, respiratory exercises, and psychological support were performed by COVID-19 survivors. This tailored and multidisciplinary rehabilitative program was found to prevent the new onset of disabilities over the short term and long term (over 6 months). Moreover, incorporating health resort medicine and balneotherapy into rehabilitation programs can reduce the economic burden on healthcare system (*191*). Ogonowska-Slodownik *et al*. conducted a RCT to compare the effects of rehabilitation using hydrotherapy and land-based exercise in 74 children with post-COVID conditions (*192*). Oxygen uptake values were found to increase in both the hydrotherapy and land-based groups. There were no significant differences in fatigue-related indices. The land-based group had better results with regard to the QOL domain.

The impacts of SARS-CoV-2 infection are known to be systemic. Almost all systems and all organs in the human body can theoretically be affected by COVID-19 (*185*). Accordingly, various symptoms might manifest due to the dysfunction of a certain system/organ. Hydrotherapy is feasible for rehabilitation of COVID-19-related symptoms, and long COVID-related disabilities and deficits in particular. More studies are expected to investigate this topic.

5. Adverse events and contraindications

Hydrotherapy-related adverse events, and particularly severe adverse events, have rarely been reported. Most of the available studies have reported that "no adverse effects were observed," hydrotherapy-related adverse events cannot be ignored, and this is especially true for patients with certain conditions. Fatigue and exhaustion are the most commonly reported adverse events in patients with cancer after undergoing hydrotherapy (*193,194*). Short-term edema (*193*) and increased pain (*195*) have been sporadically reported in patients with cancer. One study on OA reported that a patient withdrew from hydrotherapy owing to low back pain (*196*). However, none of these studies reported whether these problems could be attributed to hydrotherapy.

Hydrotherapy is performed in an artificial environment, and the intervention protocol (treatment duration, frequency, *etc*.) and parameters (water temperature, pool size, *etc*.) are strictly managed by the therapist. Excessive hydrotherapy may result in a sports injury, so the therapist should devise an appropriate hydrotherapy protocol while fully considering the physical and pathophysiological state of a given patient to avoid adverse events. Moreover, the establishment of strict but feasible criteria for indications and contraindications of hydrotherapy would help clinicians to select (or exclude) those patients who are suited (or unsuited) to hydrotherapy.

Patients with contraindications to land-based rehabilitation are unsuitable for hydrotherapy. However, hydrotherapy-related contraindications have not yet been comprehensively reported. Based on the available literature and our own experience, several issues should be considered.

i) Hydrotherapy-induced infection is the first noteworthy problem because a hydrotherapy pool with a water temperature above 30°C is a favorable environment for microbial growth. Owing to the strict daily management of the water quality of the hydrotherapy pool, the prevalence of hydrotherapy-related infections is extremely low, even in patients with external fixation who are susceptible to infection. A recent study investigated hydrotherapy-related infections in patients who underwent external fixation, and it found that only 32 of 1,200 sessions (3%) were missed because of secretions or other signs of infection (*197*). Thus, hydrotherapy-related infection is controllable if the water quality is strictly managed and the participating patients are carefully selected. Hydrotherapy is only suitable for infection-free patients (*197*). A confirmed infection or signs of infection are contraindications for hydrotherapy.

ii) Hydrotherapy-related changes in the blood circulation are another non-negligible problem. That said, temperature and pressure stimuli due to water might improve circulatory function and benefit patients with cardiovascular disease. Water pressure compresses the superficial veins of the extremities, resulting in increased blood volume in the chest, 26–34% of which is allocated to the heart, effectively expanding the functional capacity and hemodynamic parameters of the left ventricle. In addition, warm water (32–34°C) enhances the influence of the parasympathetic nervous system and induces bradycardia, decreased blood pressure, and vascular resistance by stimulating the pressure receptors (*198*). That said, hydrotherapy may be harmful to patients with heart disease. Meyer and Bücking reported that hydrotherapy induced abnormal mean pulmonary artery pressure and mean pulmonary artery pressure in patients with myocardial infarction and chronic congestive heart failure(*199*). Left ventricular overload and stroke volume have been noted in patients with severe congestive heart failure. A point worth noting is that many patients still feel good during hydrotherapy, regardless of hemodynamic deterioration (*199,200*). Accordingly, severe heart conditions such as heart failure and myocardial infarction are contraindications for hydrotherapy.

iii) Considering the special aquatic environment, some dermatoses, such as eczema, psoriasis, and chronic pruritus, were put forward as contraindications for hydrotherapy according to a French study (*201*).

6. Concluding remarks

The current study conducted a comprehensive review investigating the clinical applications of hydrotherapy, with a focus on athletic rehabilitation and neurorehabilitation based on the latest available evidence. The aim of this study was to provide updated information to all rehabilitation researchers. Although the application of hydrotherapy extends beyond the diseases discussed in this paper, the take-home messages should benefit those who are engaging in the research/practice of hydrotherapy. Based on the aforementioned insights as well as on our clinical experience thus far, we offer several suggestions that might benefit future research:

i) Combining hydrotherapy with other treatments: Mounting evidence cited in this study has corroborated that the combined use of hydrotherapy and other treatments [land-based exercises, medication, surgery, and other treatments such as direct-current stimulation (*202*)] has a better efficacy than hydrotherapy alone. Thus, combined therapeutic programs should be designed after considering the pathophysiological state of a given patient so as to reap the maximal benefits.

ii) Attention needs to be paid to the barriers associated with participation in hydrotherapy. Compared to conventional land-based exercise, hydrotherapy requires special facilities and a well-trained therapist or coach, making it more expensive and potentially discouraging low-income patients. Thus, the government and the health insurance system should offer added support for hydrotherapy. The location of the hydrotherapy facility must be seriously considered since access to a facility is a determining factor for the patient and his or her family with regards to continuing hydrotherapy. Thus, a hydrotherapy center for geriatric diseases needs to be established in or near where the elderly live or in a geriatric hospital to increase adherence.

iii) Development of hydrotherapy-specific assessment tools should be considered. Thus far, almost all outcome measures for hydrotherapy are the same as those used for land-based therapies. However, the environment in the water is quite different from that on the land. Thus, tools that are specific to an aquatic environment need to be developed. The principles of OMS as mentioned for development of PD-related behavioral assessments (*119-121*) are applicable to the development of those tools.

iv) Tasks and equipment in hydrotherapy should be developed in a disease-specific manner. Different diseases have their own pathophysiological characteristics. Thus, disease-specific tasks/equipment might have better efficacy and safety for the patient. When, for example, using an ATM for PD, it should have a lower speed, a task of a shorter duration, and better protection should be provided since patients with PD always have a higher risk of falls than other patients

v) Use of the latest computer technologies should be considered in hydrotherapy: With the development of sensors, physiological parameters can be measured in real time (*119*), which can allow the therapist to ascertain the patient's state and adjust the training exercise in a timely manner. Well-developed motor analysis software with a camera to dynamically capture kinetic motion can help the clinician to understand the motor characteristics of a particular patient and then design a more appropriate training exercise plan. VR-based equipment is also helpful to simulate various training scenarios, thereby improving the exercise. A robot-assisted hydrotherapy system would help to resolve the problem of the dearth of therapists. Miyoshi *et al*. developed a robotic gait trainer that can be used in walking exercises on a treadmill in water, and they found that this equipment improved the effects of both hydrotherapy and land-based treadmill gait training (*203*). Moreover, artificial intelligence technology with machine learning could be used to design a rehabilitation program, evaluate the effectiveness of training, and improve the training program. However, there are few studies on these topics. Studies that provide robust evidence regarding the application of computer technologies to hydrotherapy are highly anticipated.

In conclusion, more novel hydrotherapy-related techniques are emerging with advances in science and technology. The value of hydrotherapy should be recognized by more people, including clinicians and patients. Along with land-based rehabilitation, hydrotherapy may lead to a better future.

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