Chapter

# Water-Based Wellness: Unlocking Physical Resilience and Functional Longevity in Ageing Population

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## Abstract

As the global population ages, a pressing gap emerges between lifespan and health span marked by chronic degeneration, immobility, and psychosocial decline. Traditional geriatric care often fails to address the complex interplay of physical, emotional, and cognitive wellness. This chapter explores hydrotherapy as a transformative, science-backed intervention in geriatric care. Drawing from physiology, neuroscience, and rehabilitation medicine, it outlines how water-based therapy supports function preservation, joint health, balance, and cardiovascular safety while also reducing anxiety, isolation, and fear of falls. With principles grounded in buoyancy, thermodynamics, and hydrostatic pressure, hydrotherapy creates a joint-friendly environment that fosters movement without strain. The chapter also reviews various modalities including warm water therapy, aquatic tai chi, contrast baths, and underwater treadmill training, comparing their outcomes with land-based therapies. Practical models for integrating hydrotherapy into elderly routines are also presented, along with strategies to overcome barriers like infrastructure, cost, and professional availability. By linking clinical evidence with real-world applications, this text presents hydrotherapy not just as a rehabilitative tool but as an essential component of preventive strategy that enhances autonomy, dignity, and long-term well-being in older adults.

**Keywords:** geriatric wellness, low-impact exercises, hydrotherapy, healthy ageing, fall prevention

## 1. Introduction

The world is undergoing a demographic shift, with people over 60 years expected to outnumber those under 15 for the first time in history by 2050 [1]. This transition brings with it an urgent concern: how do we ensure quality of life, not just longevity? Ageing is inherently accompanied by chronic degenerative processes like decreased joint flexibility, reduced vascularity, generalised sarcopenia and neurological decline [2]. These factors contribute to disability associated with falls, reduced functional independence, and increased healthcare dependency among the elderly. Amidst this, we face a pressing "wellness gap," the growing division between lifespan and

health-span. While advances in medicine have extended human life expectancy, they have not proportionately improved the years lived in good health. This paradox presents both a clinical challenge and an opportunity for how we maintain function, mobility, and dignity as people age. Hydrotherapy, a therapeutic approach involving the use of water for pain relief and treatment, is emerging as a promising solution. By harnessing the principles of buoyancy, resistance, hydrostatic pressure, and temperature, hydrotherapy allows ageing individuals to engage in functional activity without the strain imposed by gravity [3]. The buoyancy of water reduces joint load, enabling movement even in individuals with osteoarthritis or frailty. Hydrostatic pressure improves venous return and circulation, while warm water supports muscle relaxation and pain modulation [4]. Multiple randomised controlled trials and meta-analyses support the effectiveness of hydrotherapy, like Vivas et al. [5] found that aquatic therapy significantly improved balance and reduced the fear of falling in community-dwelling older adults. Another study by Noh et al. [6] highlighted improved gait patterns and confidence among stroke patients receiving aquatic therapy, illustrating its neurological benefits. Psychologically, hydrotherapy has also been shown to reduce symptoms of anxiety and depression and to increase motivation for physical activity among the elderly [7]. These findings align with the biopsychosocial model of ageing, emphasising the interdependence of mind and body in therapeutic outcomes. Incorporating hydrotherapy into ageing care offers a regenerative model—one that not only rehabilitates but revitalises. It bridges the gap between ageing and wellness by restoring function, dignity, and autonomy. As healthcare systems grapple with ageing populations, hydrotherapy represents an integrative, evidence-based tool for future-ready rehabilitation.

A compelling example of this integrative potential can be found in the National Health Service (NHS) in the United Kingdom, where community hydrotherapy programmes are being implemented for elderly patients with osteoarthritis, Parkinson's disease, and post-stroke impairments. In these programmes, patients report not only improvements in functional independence and balance but also reductions in pain perception and fear of falling [5, 7]. This model reflects the evolving approach in geriatric rehabilitation, which increasingly prioritises holistic, person-centred care. It emphasises functional improvement rather than merely managing symptoms and promotes proactive maintenance instead of reactive crisis intervention. However, the development and implementation of such comprehensive care systems remain limited. These progressive shifts are primarily observed in well-developed regions and advanced healthcare settings. The true challenge lies in underserved and under-resourced areas, where ageing populations continue to struggle for basic functional mobility and pain-free quality of life.

## 2. Geriatric wellness: The emerging crisis

The emerging crisis is not merely about longevity but the capacity to live well in advanced age. Ageing populations are exerting tremendous pressure on healthcare systems worldwide. While life expectancy has increased substantially, this has not been matched by a proportional rise in "Health-Adjusted Life Expectancy" (HALE)—a metric that quantifies years lived without disability [8]. In many countries, particularly those with ageing societies like Japan, Italy, and Germany, the final decades of life are increasingly characterised by comorbidities, frailty, cognitive decline, and loss of autonomy. This rising burden is especially challenging for

healthcare economies. For instance, in the United States, over 80% of older adults live with at least one chronic condition, such as arthritis, hypertension, diabetes, or heart disease, and more than 60% live with two or more [9]. The financial cost of treating chronic illnesses in the elderly consumes a significant share of national healthcare budgets. Moreover, these "Geriatric syndromes" often lead to repeated hospitalisations, long-term medication use and a growing dependence on social and caregiver support systems, thereby intensifying economic and societal strain. The concept of these syndromes captures a set of multifactorial conditions that are not tied to a single disease process but have shared risk factors and significant impacts on functionality and quality of life. These include frailty, falls, urinary incontinence, cognitive impairment, pressure ulcers, and delirium [10]. Such syndromes often interact in complex ways, leading to a cascade of functional deterioration and reduced resilience in older adults. For example, frailty, a clinical syndrome characterised by unintentional weight loss, weakness, exhaustion, slow walking speed, and low physical activity, affects approximately 10–15% of community-dwelling older adults [11]. Frail individuals are more susceptible to hospitalisation, disability, and mortality, even after minor stressors like a cold or a brief period of immobility. Similarly, sarcopenia and osteoporosis lead to impaired mobility and an increased risk of falls, which are the leading cause of injury-related deaths in adults over 65 [12]. These physical declines are often compounded by cognitive syndromes such as mild cognitive impairment or dementia, creating a multidimensional burden on the individual and their support systems.

One of the central paradoxes in modern ageing is the widening gap between longevity and quality of life. Medical advancements have significantly prolonged human lifespan, but these extra years are frequently accompanied by a progressive decline in autonomy, purpose, and engagement. This paradox is stark: while people are living longer, they are not necessarily living better. The concept of "compression of morbidity," proposed by Fries [13], suggests that with effective preventive strategies, the period of disability and illness before death can be shortened, thereby enhancing the quality of life even as people live longer. However, in reality, many older adults experience an "expansion of morbidity," where chronic diseases and disabilities extend over

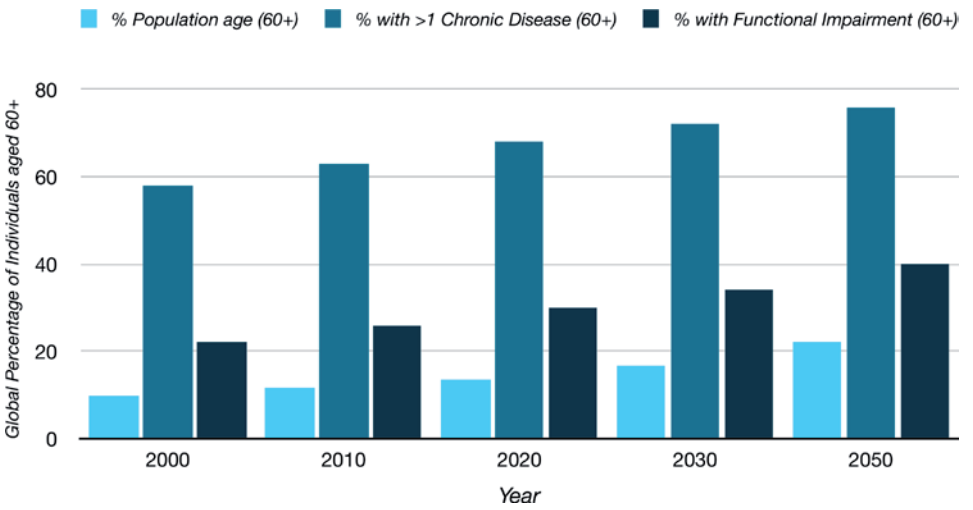



**Figure 1.**
*The above data illustrates the rising global burden of ageing, chronic disease prevalence and functional decline in older adults from 2000 to projected levels in 2050 [1, 15–17].*

many years. The misalignment between years lived and years lived well is not only a medical concern but a philosophical and ethical one. Increasing evidence shows that psychosocial factors—such as loneliness, loss of purpose, and social isolation—have a measurable impact on health outcomes, often equating in significance to traditional risk factors like smoking and obesity [14]. Thus, the solution lies not merely in adding years to life but in adding life to years. A function-oriented model of ageing must prioritise mobility, independence, cognitive vitality, and social participation. The WHO's Decade of Healthy Ageing (2021–2030) [1] emphasises intrinsic capacity: the composite of all the physical and mental capacities an individual can draw on and functional ability as central goals for health systems (**Figure 1**).

As the geriatric wellness crisis looms larger, it is no longer sufficient to view ageing as a medical condition. It is a complex life stage requiring a multidisciplinary approach that spans biology, behaviour, environment, and policy. The goal should not be simply to extend life but to ensure that those additional years are meaningful, active, and dignified.

## 3. Functional ageing under pressure: Systemic and psychosocial barriers

Ageing is intrinsically associated with a progressive deterioration of musculoskeletal integrity, which critically undermines functional independence in the elderly. Among the most prominent manifestations of this decline is sarcopenia, a condition marked by the gradual and debilitating loss of skeletal muscle mass, strength, and endurance. This multifactorial syndrome arises through complex physiological processes that converge to weaken the neuromuscular system. The primary physiological precursor responsible for initiating the cascade is neuromuscular degradation, where ageing-associated functional decline and reduced muscle force output lead to a marked reduction in both the quantity and functionality of α-motor neurons. This decline impairs motor unit recruitment and induces muscle fibre denervation and subsequent atrophy, particularly of fast-twitch fibres, resulting in diminished coordination, slower reflexes, and increased susceptibility to falls [18]. Additionally, age-related hormonal alterations further exacerbate sarcopenia. A decline in anabolic hormones such as testosterone, growth hormone (GH), and insulin-like growth factor-1 (IGF-1) impairs protein synthesis pathways that are essential for muscle hypertrophy and regeneration. The reduction in IGF-1 in particular limits the activation of satellite cells which are crucial for muscle repair, thus weakening the body's adaptive response to muscular stress or injury [19]. Simultaneously, mitochondrial dysfunction plays a pivotal role in accelerating muscular degradation. With ageing, mitochondria exhibit decreased oxidative phosphorylation efficiency and increased production of reactive oxygen species (ROS), leading to ATP insufficiency and elevated oxidative damage within muscle fibres. This imbalance disrupts cellular homeostasis and induces apoptotic signalling, which promotes muscle cell death and further amplifies sarcopenic progression [20]. Together, these interlinked mechanisms create a physiological cascade that not only erodes muscle performance but also compromises mobility, resilience to stress, and quality of life in ageing individuals (**Figure 2**). Understanding these mechanisms underscores the importance of early intervention strategies targeting neuromuscular health, hormonal balance, and mitochondrial function in order to preserve functional longevity and reduce dependency in the elderly.

In parallel with muscular decline, ageing also brings about progressive joint dysfunction, with osteoarthritis (OA) emerging as one of the most common and

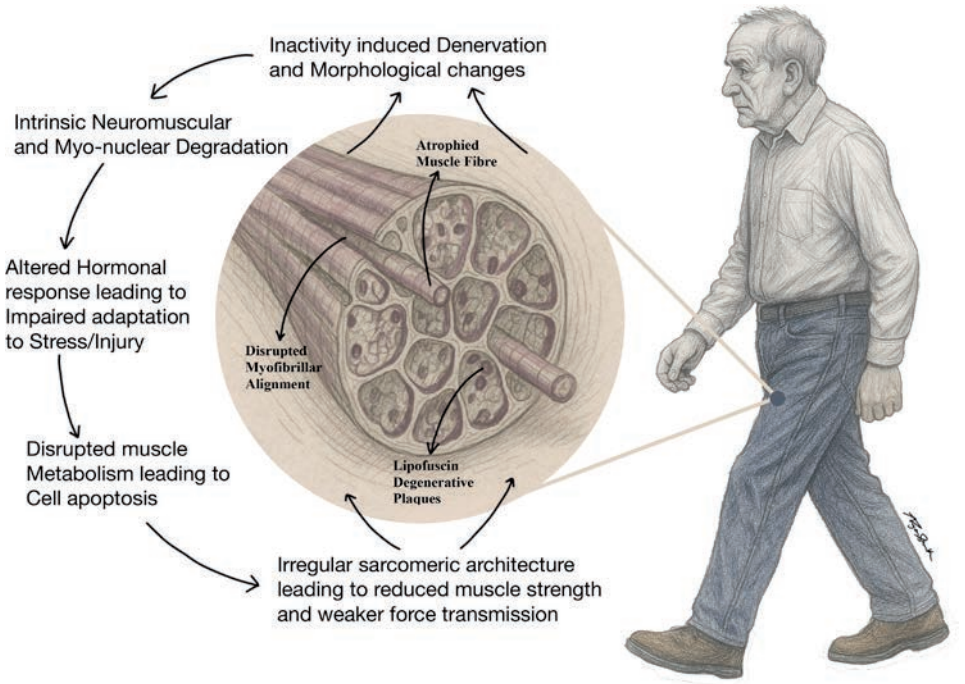



**Figure 2.**
*The sarcopenic cascade—a progressive degeneration leading to muscle weakness and impaired functional capacity [18, 20].*

debilitating conditions affecting older adults. The pathogenesis of OA is primarily driven by the degradation of articular cartilage, which serves as a shock-absorbing surface within joints. With advancing age, chondrocytes, the specialised cells that maintain the volume of cartilage, exhibit reduced autophagic activity, impairing their ability to clear damaged cellular components. Simultaneously, these ageing cells up-regulate the production of matrix metalloproteinases (MMPs) and other catabolic enzymes, leading to accelerated extracellular matrix breakdown and a consequent loss of chondral integrity. These changes result in a narrowing of the intra-articular space with extra-articular irritation and pain, leading to a decreased range of motion [21]. Beyond the cartilage, subchondral bone - the layer of bone just beneath the cartilage, also undergoes age-related remodelling impairments. Ageing disturbs the balance between bone resorption and formation, leading to increased bone fragility, microfractures, and structural instability across load-bearing articular surfaces of the major joints such as hips and knees. This compromised support accelerates the degenerative cycle, further weakening joint mechanics and function. The combined effects of musculoskeletal decline and age-associated sensory deterioration including reduced visual acuity, impaired proprioception, and progressive vestibular dysfunction substantially heighten the risk of falls in older adults. These deficits compromise spatial awareness and dynamic balance, making individuals more prone to tripping, misstepping, or experiencing disorientation, all of which directly impair postural stability and coordination. As a result, comprehensive fall prevention strategies become a necessity in geriatric care.

While physical deterioration is a hallmark of ageing, the psychosocial challenges that accompany later life stages often remain un recognised and untreated, despite

their profound impact on overall health and functional independence. Social isolation is common among older adults due to retirement, bereavement, reduced mobility, or institutionalisation, which is more than a social concern with deep physiological and neurological repercussions. Studies demonstrate that social disconnectedness is associated with accelerated cognitive decline, particularly due to the lack of mental and emotional stimulation, which reduces synaptic activity and neuroplasticity, thus increasing the risk of dementia [22]. Moreover, loneliness has been correlated with elevated levels of cortisol and inflammatory cytokines such as interleukin-6 (IL-6) and C-reactive protein (CRP), contributing to hypertension and cardiovascular morbidity. In parallel, depression and anxiety are prevalent yet frequently underdiagnosed in elderly populations. This under-diagnosis often results from overlapping symptoms with other medical conditions and the false assumption that low mood is a normal aspect of ageing. Biologically, ageing affects neurotransmitter systems, notably serotonin and dopamine, making older individuals more susceptible to mood disorders. Additionally, life transitions such as loss of social roles, economic insecurity, and chronic illness further amplify psychological distress. According to a recent meta-analysis, global prevalence rates of depression and anxiety in older adults are approximately 19.2% and 16.5%, respectively [23], highlighting the urgent need for systematic screening and early psychological intervention.

### 3.1 The invisible burden of systemic barriers undermining geriatric health

The healthcare system often struggles to accommodate the layered, multidimensional needs of the ageing population. A key issue is the underdiagnosis and under-treatment of serious conditions due to atypical presentations. For instance, myocardial infarction in the elderly may occur without chest pain, and infections may present without classic febrile responses due to blunted immune reactivity [24]. Ageism in clinical decision-making leads to the erroneous belief that symptoms are part of "natural ageing," resulting in therapeutic nihilism and delayed interventions. Furthermore, communication gaps arising from sensory deficits such as hearing loss or cognitive impairments hinder proper history-taking, treatment adherence, and follow-up care. Compounding this, caregiver strain is a critical but frequently neglected domain. Caregivers, particularly family members, face intense emotional and psychological burdens, including guilt, anxiety, and burnout, especially when caring for individuals with dementia or complex disabilities [25]. The physical demands of caregiving can result in musculoskeletal injuries, while financial stress arises from reduced employment opportunities, lack of insurance support, and minimal access to respite care. In low- and middle-income regions, where geriatric infrastructure is sparse, these challenges are significantly magnified. Fragmented healthcare systems, insufficient training for home-based care, and limited access to mental health services create a persistent cycle of unmet needs, accelerating functional decline and leading to caregiver exhaustion. As a result, the combined impact of physiological, psychosocial, and systemic challenges significantly undermines geriatric care and functional longevity across multiple domains, particularly beyond the early stages of ageing (**Table 1**). Another critical and often underestimated contributor is polypharmacy, commonly defined as the use of five or more medications. It is a growing concern in geriatric care, with prevalence rates exceeding 40%, as older adults are frequently prescribed multiple medications for chronic conditions [26]. Many of these drugs, including antihypertensives, sedatives, and antidepressants, are associated with side effects like dizziness, orthostatic hypotension, and delayed

| Sr. no. | Domain | Challenges |
|---|---|---|
| (1) | Physical decline | Sarcopenia |
| | | Joint dysfunction and osteoarthritis |
| | | Increased risk of falls |
| (2) | Neuromuscular function | Mitochondrial dysfunction |
| | | Motor neuron loss and denervation |
| | | Central motor control deficits |
| (3) | Psychosocial limitations | Social isolation |
| | | Depression and anxiety |
| (4) | Systemic healthcare issues | Under-diagnosis of conditions |
| | | Under-treatment and delayed interventions |
| | | Caregiver but put and strain |

**Table 1.**
*Key physiological, psychosocial, and systemic challenges affecting geriatric care and functional longevity [18, 21, 23, 25].*

reaction time, which directly impair balance and coordination. While necessary for managing multiple chronic conditions, polypharmacy increases the risk of adverse drug events (ADEs) that directly impair physical and cognitive function. Medications such as antihypertensives can cause orthostatic hypotension, sedatives can lead to drowsiness and impaired motor coordination, and antidepressants may provoke dizziness and delayed reaction times—all of which elevate the likelihood of falls [27, 28]. Furthermore, drug-drug interactions (DDI) and age-related changes in pharmacokinetics and pharmacodynamics compound these risks. Therefore, regular medication reviews and deprescribing protocols should be integral to holistic fall prevention strategies in geriatric rehabilitation.

## 4. Models and strategies for promoting geriatric wellness

Promoting geriatric wellness is a multifaceted endeavour that necessitates a comprehensive understanding of ageing processes and the implementation of holistic strategies. This discussion delves into three pivotal components: the World Health Organisation's (WHO) frameworks for healthy ageing, multidimensional and biopsychosocial models, and the integral roles of exercise, socialisation, and engagement.

### 4.1 WHO frameworks for healthy ageing

The WHO has been at the forefront of advocating for healthy ageing, emphasising the importance of maintaining the functional ability to ensure well-being in older age. Their approach is encapsulated in the "Decade of Healthy Ageing (2021–2030)," a global initiative aimed at improving the lives of older people, their families, and communities [1]. Central to this framework is the concept of "functional ability," which refers to the health-related attributes that enable people to be and do what they value. This encompasses the capacity to meet basic needs, learn and make decisions, be mobile, build and maintain relationships, and contribute to society [15]. The WHO's

approach underscores the need for action across multiple sectors, including health, education, labour, and social protection, to create environments that support healthy ageing. This holistic perspective recognises that ageing is not solely a health issue but is influenced by a myriad of social and environmental factors.

### 4.2 Multidimensional and biopsychosocial models

Understanding ageing through a multidimensional and biopsychosocial lens is essential for constructing comprehensive strategies that truly promote geriatric wellness. These models help us move beyond a disease-centric perspective to one that acknowledges the complexity and diversity of ageing experiences across individuals. The biopsychosocial model, first introduced by George Engel in 1977, emphasises that health outcomes are shaped not solely by biological mechanisms but also by psychological states (such as cognition, emotion, and motivation) and social environments (including relationships, support systems, and socioeconomic status) [29]. In geriatric care, this model provides a valuable framework for addressing both the visible and hidden aspects of ageing. For example, an elderly patient with osteoarthritis may also be experiencing depression, loneliness, and financial strain—factors that amplify pain perception, reduce adherence to treatment and compromise quality of life. Complementing this, the multidimensional model of ageing outlines key domains influencing overall well-being: physical function, cognitive health, emotional status, social engagement, functional independence, and environmental conditions [30]. This model is widely used in geriatric assessments such as the Comprehensive Geriatric Assessment (CGA), which helps clinicians evaluate older adults beyond their primary diagnosis, incorporating aspects like nutrition, mental status, mobility, and living situation to form personalised interventions [31]. These frameworks collectively challenge the reductionist notion that successful ageing is merely the absence of disease. Instead, they propose that optimal ageing includes maintaining autonomy, participating in meaningful social roles, and adapting positively to age-related changes. This aligns with Rowe and Kahn's model of successful ageing, which identifies three main components: a low probability of disease, high physical and cognitive functioning, and active engagement with life [32]. Empirical support for the biopsychosocial model continues to grow. A study comparing older adults in Pakistan and Canada found that variables such as health status, self-efficacy, social support, and self-esteem significantly influenced perceived quality of life, regardless of geographical or cultural differences [33]. These findings underscore that biopsychosocial factors are universally relevant and can guide ageing-related policy and care planning globally. Importantly, the models also acknowledge the reciprocal nature of these domains. Social isolation, for example, may reduce motivation for self-care, which in turn exacerbates health decline and increases dependency. Conversely, strong social ties and a sense of purpose can improve adherence to medical treatments, boost immune function, and mitigate stress-related damage [34]. Furthermore, incorporating psychological resilience—defined as the capacity to recover from stress or adversity—has shown protective effects in geriatric populations.

Older adults with higher resilience tend to exhibit better emotional regulation, reduced frailty, and improved cognitive outcomes, even when facing chronic illness or disability [35]. Together, the biopsychosocial and multidimensional models serve as indispensable tools for ageing research and practice. They support the idea that effective geriatric care must not only address medical issues but also nurture psychological health and create supportive environments that empower the elderly to live with dignity, purpose, and independence.

### 4.3 Role of exercise, socialisation, and engagement in geriatric wellness

Physical activity is widely recognised as a foundational component of healthy ageing, offering profound physiological, cognitive, and psychosocial benefits. Regular physical exercise contributes to the preservation of skeletal muscle mass, enhances neuromuscular coordination, and maintains cardiovascular efficiency—factors that are critical for mobility, fall prevention, and independence in older adults [36, 37]. Resistance and balance training, in particular, have been shown to reduce the risk of sarcopenia and frailty, conditions commonly associated with ageing and linked to increased morbidity and mortality [2]. Aerobic activities, such as walking, cycling, and swimming, have consistently been associated with reduced incidence of non-communicable diseases including type 2 diabetes, hypertension, stroke, and cardiovascular disease [38]. Exercise is also neuroprotective as physical activity stimulates the release of neurotrophic factors such as brain-derived neurotrophic factor (BDNF), which supports neurogenesis, synaptic plasticity, and cognitive preservation in ageing populations [39]. Beyond these physiological benefits, exercise plays a central role in enhancing psychological health. Regular movement has been shown to reduce symptoms of depression and anxiety by modulating neurotransmitter function and improving sleep quality [40]. Critically, many forms of physical activity—particularly group-based programmes—naturally foster social interaction, which is equally important for geriatric wellness. Engaging in activities like community walking groups, yoga classes, or recreational sports provides not only motivation for sustained participation but also strengthens a sense of belonging, combats loneliness, and improves emotional well-being [41, 42].

Socialisation, as a determinant of healthy ageing, extends beyond exercise. According to the activity theory of ageing, older adults achieve greater life satisfaction and better functional outcomes when they remain socially engaged in roles that provide meaning and stimulation [43]. Active participation in social activities such as religious gatherings, hobby clubs, or cultural events contributes to enhanced mood, cognitive resilience, and even decreased mortality risk [14, 44]. Community engagement further amplifies these benefits by offering older adults a sense of agency and purpose. Volunteering, participating in civic activities, or mentoring younger generations allows individuals to maintain a meaningful identity and remain integrated in societal structures. Data from the National Health and Aging Trends Study (NHATS) demonstrate that older adults who regularly engage in physical and social activities report higher levels of psychological well-being, reduced functional decline, and slower cognitive deterioration [45]. In sum, integrating physical activity with meaningful social interaction and community participation is essential for promoting holistic wellness among older adults. These lifestyle behaviours not only mitigate the risks associated with physiological ageing but also foster emotional resilience, cognitive health, and a sense of purpose, all of which are crucial for maintaining the quality of life in later years.

## 5. Principles of hydrotherapy: Scientific basis and application in geriatric care

Hydrotherapy is known as a form of therapy which refers to the clinical application of water in various temperatures, states (liquid, steam, or ice), and delivery

methods (immersion, compresses, jets, etc.) to treat a range of pathological conditions by utilising its mechanical and thermal effects. It has become increasingly recognised in modern rehabilitation settings for its diverse, evidence-backed physiological and psychological benefits. Particularly in geriatric populations, hydrotherapy represents a multidimensional therapeutic tool that not only targets biomechanical impairments but also addresses underlying circulatory, neurological, and psychosocial deficits often neglected in conventional land-based rehabilitation approaches. As individuals age, they encounter a progressive decline across various physiological systems. In such cases, hydrotherapy provides a safe, supportive, and low-impact environment that mitigates these limitations while maximising functional physiological gains (**Table 2**).

| Sr. no. | Physiological system | Adaptation | Clinical outcome |
|---|---|---|---|
| (1) | Musculoskeletal system | Improved density of type 2a muscle fibres | Enhanced response ability of the soft tissues under load resulting in better movement quality. |
| | | Enhanced mitochondrial volume | |
| | | Improved joint play | |
| (2) | Neuromuscular system | Enhanced firing of alpha motor neurons | Improved response time with better sense of stability and postural control while in motion or change of direction. |
| | | Improved efferent conductivity of neurons | |
| | | Enhanced excitability of the central motor pools | |
| (3) | Cardiovascular system | Improved cardiac dynamics and symmetry | Improved coherence between physiological load and associated cardiac changes. |
| | | Improved coronary circulatory efficiency | |
| (4) | Pulmonary system | Improved alveolar sensitivity | Improved pulmonary endurance and functional capacity resulting in enhanced locomotory ability |
| | | Improved parenchymal micro circulation | |
| (5) | Endocrine system | Improved insulin sensitivity | Improved glycemic control with reduction in cardiovascular risk. |
| | | Improved hormonal associated mechanical gains | |
| (6) | Immune system | Improved lymphatic drainage and circulation | Better chemical response of the body towards exercise which enhances exercise related sensitivity of the body and long-term adaptations. |
| | | Reduction in production of inflammatory markers | |
| | | Decreased low grade inflammation across joints | |

**Table 2.**
*System-specific physiological adaptations induced by hydrotherapy in geriatric individuals [3].*

## 5.1 Thermodynamic effects of hydrotherapy

The thermodynamic properties of water—specifically its temperature regulation capacity—are fundamental to hydrotherapy's therapeutic value, particularly in geriatric populations. Water can be precisely temperature-controlled, making it an ideal medium for delivering targeted thermal interventions, whether to relax muscles, reduce inflammation, modulate neural activity, or enhance circulation [46].

### *5.1.1 Warm water immersion (33–36°C)*

Warm water therapy is most commonly used in rehabilitation settings for elderly patients. Immersion in water at thermoneutral to mildly warm temperatures (33–36°C) offers several physiological and therapeutic benefits.

#### *5.1.1.1 Vasodilation and improved peripheral circulation*

Heat causes vasodilation of cutaneous and muscular blood vessels, increasing blood flow to peripheral tissues. This enhances oxygen delivery and waste product removal, promoting tissue healing and reducing stiffness in age-compromised musculoskeletal structures [47]. This is particularly beneficial in elderly patients with peripheral artery disease, diabetes-related microvascular issues, or chronic cold extremities.

#### *5.1.1.2 Reduction in muscle tone and joint stiffness*

Warmth helps decrease alpha motor neuron excitability, leading to a reduction in muscle tone and spasm—a key benefit for patients suffering from post-stroke spasticity or Parkinsonian rigidity [3]. Moreover, increased elasticity of connective tissue at elevated temperatures improves joint mobility and range of motion, which is critical in conditions such as osteoarthritis, frozen shoulder, or ankylosing spondylitis common in older adults.

#### *5.1.1.3 Pain modulation*

The application of heat in hydrotherapy activates thermo receptors that override nociceptive input *via* the gate control theory of pain. This results in immediate analgesic effects without pharmacological side effects, making it a preferred option in geriatric patients who often have polypharmacy concerns or contraindications for NSAIDs.

#### *5.1.1.4 Facilitation of gentle exercise*

When combined with the effects of buoyancy and hydrostatic pressure, warm water further allows elderly individuals with limited mobility to perform exercises that may be too painful or difficult on land. The warmth reduces joint friction, promoting safe movement initiation and prolonged activity tolerance, especially in frail or deconditioned elderly individuals.

#### *5.1.1.5 Improved sleep and autonomic nervous regulation*

Research indicates that warm water immersion has a parasympathetic-dominant effect, reducing sympathetic tone and promoting relaxation. This leads to reduced

heart rate, improved sleep quality, and lowered cortisol levels. Improved autonomic regulation is essential in older adults, many of whom suffer from insomnia, hypertension, or anxiety. Warming the body mildly increases metabolic rate, which can enhance tissue oxygenation and enzyme activity during rehabilitation. This promotes better cellular repair in aged tissues with slower healing dynamics.

*5.1.2 Contrast therapy and cold water applications (10–20°C)*

In some cases, cold or alternating hot-cold therapy (contrast hydrotherapy) is used for older adults with acute inflammation, swelling, or vascular dysfunction:

- Cold water (10–20°C) induces vasoconstriction, helping reduce inflammation, joint effusion, and delayed-onset muscle soreness after physical activity.
- Contrast hydrotherapy (alternating immersion in hot and cold water) triggers a vascular pumping effect, which can enhance lymphatic drainage and circulation, useful in managing venous insufficiency or chronic oedema.

However, cold therapy should be used cautiously in older individuals due to their reduced thermoregulatory capacity and potential for cold intolerance or cardiovascular instability [48].

*5.1.3 Therapeutic customisation based on comorbidity*

The choice of hydrotherapy temperature should always be individualised in geriatric patients [49]. For example:

- Warmer temperatures (35–36°C) are ideal for those with osteoarthritis, chronic back pain, or fibromyalgia to promote muscle relaxation and pain relief.
- Moderate temperatures (31–33°C) are used for cardiopulmonary compromised elderly, ensuring safe haemodynamic response during aerobic aquatic activity.
- Cooler ranges (27–29°C) may be utilised in higher-intensity aquatic exercise where heat stress or fatigue must be minimised.

The thermodynamic properties of water—particularly warm water—are central to hydrotherapy's clinical utility in geriatric rehabilitation. By harnessing these thermal effects, clinicians can address pain, stiffness, circulation, and neuromuscular tone holistically. Warm water immersion offers a low-risk, high-benefit intervention for ageing populations who often face limitations in conventional physiotherapy. When designed with accessibility, individualised protocols, and safety in mind, hydrotherapy becomes a cornerstone modality for promoting functional independence and quality of life in older adults [3, 47, 50].

## 5.2 The therapeutic triad in aquatic therapy

Aquatic therapy utilises the unique mechanical properties of water—buoyancy, viscosity, and hydrostatic pressure—to create a safe, effective, and therapeutic environment, especially beneficial for elderly individuals or those with physical impairments.

### *5.2.1 Buoyancy: Reducing load, enabling movement*

Buoyancy is governed by Archimedes' principle, which states that any object submerged in a fluid is acted upon by an upward force equal to the weight of the fluid displaced. In practical terms, this means that the body experiences a reduction in gravitational load when immersed in water. According to Becker [3], immersion to the level of the xiphoid process (mid-chest) reduces effective body weight by approximately 60%, while immersion to the neck can reduce it by nearly 90% [3].

This offloading effect significantly decreases joint compression forces, making it easier for individuals with arthritis, osteoporosis, or general frailty to perform movements that would otherwise be painful or impossible on land. It encourages mobility, improves joint range of motion, and reduces pain without the risk of fall-related injuries. Thus, buoyancy allows for safe and supportive rehabilitation, particularly for the elderly or those recovering from musculoskeletal injuries.

### *5.2.2 Viscosity: Natural resistance for strength and control*

Viscosity refers to the internal friction within the water that resists the movement of objects through it. Unlike static weights or fixed resistance machines on land, water provides constant, multidirectional, and self-adjusting resistance. The faster or larger the movement, the greater the resistance encountered. This unique property allows individuals to tailor the intensity of exercise subconsciously based on their capabilities.

A research article highlighted that this natural resistance helps improve muscle strength, coordination, and balance, all within a safe, low-impact environment. Importantly, it also promotes motor learning and neuromuscular control, which are essential for elderly individuals with impaired proprioception, sarcopenia, or balance disorders [51]. Furthermore, resistance training in water helps to preserve lean muscle mass and functionality, which is crucial for improving balance responses during unexpected movements or falls, ultimately supporting independence in older adults [52].

### *5.2.3 Hydrostatic pressure: Enhancing circulation and stability*

Hydrostatic pressure is the uniform force exerted by water on the body's surface, increasing with depth. This pressure acts as a gentle compression garment, aiding in venous return, reducing limb oedema, and stabilising joints during movement. It provides a key circulatory benefit for elderly individuals suffering from chronic venous insufficiency, varicose veins, or orthostatic intolerance.

The hydrostatic pressure supports haemodynamic stability, improves cardiovascular efficiency, and reduces the orthostatic load, making it easier for individuals to exercise without dizziness or fatigue [53]. Additionally, the pressure stimulates cutaneous and proprioceptive receptors, enhancing sensory feedback. This is particularly beneficial for individuals with diabetic neuropathy, vestibular dysfunction, or impaired motor control, as their reduced sensory integration makes improvements in balance, walking efficiency, and overall independence especially impactful [54].

## 6. Therapeutic water-based interventions for the elderly

As ageing populations grow worldwide, so does the need for safe, effective, and adaptable rehabilitation methods. Hydrotherapy—the use of water for therapeutic

purposes—has emerged as a powerful intervention for older adults, especially those facing chronic pain, reduced mobility, cardiovascular limitations, or musculoskeletal degeneration. Various types of hydrotherapy offer targeted physiological and psychological benefits by leveraging water's inherent mechanical and thermal properties such as buoyancy, viscosity, hydrostatic pressure, and thermal conductivity [3]. This chapter outlines five evidence-supported hydrotherapy modalities that are particularly suitable for elderly individuals.

### 6.1 Warm water pool therapy

Warm water pool therapy, also referred to as aquatic physical therapy or balneotherapy, involves performing therapeutic exercises in a temperature-controlled pool, typically maintained between 32°C and 34°C (89.6–93.2°F). This modality utilises buoyancy to reduce joint loading, viscosity for gentle resistance, and warmth to relax muscles and increase blood flow [7]. For older adults with osteoarthritis, rheumatoid arthritis, osteoporosis, or generalised frailty, warm water immersion significantly reduces pain and stiffness, enhancing joint mobility and functional independence [55]. The thermal effect also stimulates parasympathetic activity, aiding in stress relief and improved sleep quality. According to Becker [3], immersion to chest depth reduces weight bearing by up to 60%, allowing elderly individuals to perform movement without the fear of falling or pain-induced hesitation. Additionally, warm water therapy enhances cardiovascular function without the overexertion commonly associated with land-based aerobic exercises, making it a safe choice for individuals with mild to moderate cardiac conditions.

### 6.2 Aquatic Tai Chi or Ai Chi

Aquatic Tai Chi and water-based yoga combine the benefits of slow, mindful movement with the therapeutic environment of warm water. These practices emphasise balance, breath control, flexibility, and mental focus, making them ideal for elderly individuals with postural instability, cognitive decline, or chronic stress. The buoyancy of water supports slow, fluid movements, allowing older adults with joint limitations, Parkinson's disease, or post-stroke conditions to participate without overexertion. According to Tsang and Hui-Chan [56], aquatic Tai Chi significantly improved balance control and reduced the risk of falls in older individuals. Moreover, the meditative aspect of aquatic yoga or Tai Chi enhances mind-body awareness, promoting parasympathetic dominance, reducing anxiety, and improving mood [57]. Such interventions are especially valuable in combating social isolation and depression, common challenges in ageing populations.

### 6.3 Deep water walking/treadmill and resistance therapy

Technological advancements in hydrotherapy have introduced the use of underwater treadmills and adjustable resistance jets, allowing precise control of exercise intensity in a safe, supportive medium. Walking or jogging on a submerged treadmill reduces the impact on joints while still providing cardiovascular and musculoskeletal benefits (**Figure 3**) [58]. This form of therapy is highly suitable for elderly patients recovering from hip or knee replacements or those with sarcopenia and gait abnormalities. The water's resistance challenges multiple muscle groups while simultaneously enhancing proprioception and balance control. Resistance jets can be adjusted




**Figure 3.**
*The benefits of deep-water walking on an aqua treadmill for the elderly [58, 59].*

to create tailored strength-building regimens, encouraging neuromuscular coordination and endurance [59]. In studies involving geriatric patients with chronic mobility impairments, regular underwater treadmill sessions were shown to improve stride length, walking speed, and muscle activation patterns, which are vital indicators for fall risk reduction [60].

### 6.4 Immersion therapy for lymphatic and venous return

Static immersion therapy, where an individual remains passively submerged in warm water up to neck or chest level, leverages hydrostatic pressure to promote venous return, reduce oedema, and support lymphatic flow. This is especially beneficial for elderly patients with congestive heart failure, lymphedema, or chronic leg swelling [61]. Hydrostatic pressure, which increases with depth, compresses the limbs uniformly and enhances the movement of extracellular fluids, effectively reducing swelling and aiding circulation. This results in decreased discomfort, improved lower limb mobility, and prevention of venous pooling, a common issue in sedentary or immobile seniors [62]. Additionally, static immersion contributes to deep relaxation, lowering blood pressure and heart rate, while supporting cognitive clarity and

emotional well-being. When used regularly, it becomes a valuable tool in the management of vascular conditions and stress-related physiological strain.

### 6.5 Hydrogymnastics

Hydrogymnastics encompasses a range of water-based therapeutic exercises designed to improve cardiovascular fitness, strength, balance, and mobility. This modality is adaptable to various age groups, including the elderly, and can be tailored to individual needs. A study by Lima et al. [63] found that hydrogymnastics promoted an increase in agility and leg muscle strength in elderly women despite the low evidence level. Techniques such as the Bad Ragaz Ring Method (BRRM) and Watsu are integral components of hydrogymnastics.

- *Bad Ragaz Ring Method (BRRM):* Originating from Switzerland, BRRM involves therapist-assisted exercises performed while the patient is supported by flotation rings. This method utilises proprioceptive neuromuscular facilitation (PNF) patterns to enhance neuromuscular function, making it particularly beneficial for individuals with musculoskeletal and neurological conditions.

- *Watsu:* A combination of water-based Shiatsu massage and passive stretching. Watsu is performed in warm water, promoting deep relaxation, pain relief, and improved range of motion. It is especially useful for elderly individuals experiencing stress, anxiety, or chronic pain.

### 6.6 AquaStretch

AquaStretch is a relatively new technique that involves guided stretching and myofascial release in warm water. A study comparing AquaStretch with supervised land-based stretching found that AquaStretch was beneficial in reducing pain and disability [64]. The process includes four steps: play (exploring movements), freeze (identifying areas of restriction), pressure (applying manual pressure), and move (performing movements to release tension). This method has shown promise in reducing pain and improving flexibility among older adults with musculoskeletal issues.

### 6.7 Hydromassage

Hydromassage utilises water jets to deliver targeted massage therapy, promoting relaxation, pain relief, and improved circulation. This non-invasive technique is particularly beneficial for seniors, as it alleviates muscle tension and enhances mobility without placing additional strain on the body. The warmth of the water further contributes to muscle relaxation and stress reduction. HydroWorx highlights that hydromassage can enhance mobility and flexibility in ageing adults, contributing to overall wellness [65].

The evolution of hydrotherapy has introduced a variety of innovative techniques that cater to the unique needs of the ageing population. From traditional methods like hydrogymnastics and immersion therapy to cutting-edge technologies such as VR integration and smart monitoring devices, these modalities offer comprehensive benefits that address both physical and psychological aspects of health [66, 67]. Incorporating these therapies into geriatric care can significantly enhance mobility, reduce pain, and improve the overall quality of life for older adults.

## 7. Hydrotherapy: A scientific pillar in the prevention and regeneration of age-associated decline

The global ageing population is experiencing an increase in chronic, degenerative, and lifestyle-related diseases. Conditions such as cardiovascular disease, type 2 diabetes, osteoporosis, arthritis, neurodegenerative disorders, and respiratory illnesses are common among the elderly and contribute to reduced quality of life and increased healthcare burden. Preventing the onset or progression of these diseases through result-driven interventions is a vital public health priority. Ageing is associated with physiological changes that increase vulnerability to multiple diseases. These include reduced muscle mass, diminished immune function, hormonal imbalances, decreased mobility, and impaired metabolic function. When combined with sedentary lifestyles, poor nutrition, environmental stressors, and social isolation, these factors significantly elevate disease risk.

### 7.1 Global standard preventive strategies for senior citizens: Health education and literacy programmes

Educate older adults about ageing-related health risks and prevention strategies. Use age-appropriate communication in local languages, visual aids, and interactive sessions. Promote self-care practices, medication management, and health-seeking behaviour [68].

### 7.2 Routine health screening and early detection

Community-based screening for hypertension, diabetes, osteoporosis, vision, hearing, and cognitive decline. Integration of mobile clinics and primary health workers for home visits.

### 7.3 Physical activity and mobility programmes

Promote structured, supervised physical activity programmes such as walking clubs, Tai Chi, and chair exercises. Include fall prevention training and balance exercises to reduce injury risk.

### 7.4 Nutritional support and counselling

Facilitate community kitchens and meal delivery with nutrient-dense options. Provide individual or group dietary counselling focused on age-appropriate nutrition [69].

### 7.5 Social engagement and mental health promotion

Foster social participation through community centres, hobby groups, and volunteering opportunities. Train peer counsellors and social workers to detect and support cases of depression, anxiety, or dementia [70].

### 7.6 Environmental and safety intervention

Modify public and home environments to reduce fall risk (e.g., handrails, ramps, and non-slip flooring). Ensure accessible transportation and safe community spaces for the elderly.

### 7.7 Concept of bridging the global divide of the prevention and regeneration in elderly care

As the global population continues to age, the demand for preventive and regenerative healthcare interventions is reaching a critical point. Yet, a significant implementation gap exists globally—especially in low- and middle-income countries—between what is scientifically possible and what is systemically delivered. Despite evidence-based interventions available for delaying age-associated decline, their integration into mainstream care is far from optimal. Hydrotherapy, the therapeutic use of water, has long been recognised for its benefits in rehabilitation and wellness. For the elderly, it offers a gentle yet effective means to address various physical and mental health challenges. To maximise its potential, a strategic approach involving medical education, clinical integration, community awareness, and collaborative efforts is essential.

### 7.8 The prevention gap

Preventive care for older adults remains alarmingly under-addressed on the global stage. According to the World Health Organisation, out of 194 member countries, only 63% have strategies specifically focused on ageing, and merely 54% have national action plans for older adults' health [71]. Even fewer have policies to address ageism or establish long-term care systems, which directly affects the quality of life in ageing population [72]. This lack of infrastructure and policy results in a rise in avoidable chronic conditions, including sarcopenia, falls, cardiovascular strain, and neurocognitive decline. Preventive care models—such as routine movement assessments, nutritional support, and fall prevention strategies—are either inconsistently implemented or absent, particularly in resource-limited settings.

### 7.9 The regeneration shortfall

While regenerative medicine, rehabilitation, and therapies like hydrotherapy, neuroplasticity-focused interventions, and resistance-based rehab are advancing, access remains uneven. Most older adults in underprivileged family backgrounds have limited access to even basic rehabilitation services, let alone advanced regenerative protocols. According to the World Bank, healthcare systems across developing countries are "not designed for the complex, long-term needs of aging adults," often citing cost, medication access, and transportation as key barriers [73].

### 7.10 The policy mandate: WHO's decade of healthy ageing

The WHO Decade of Healthy Ageing (2021–2030) [74] presents a comprehensive framework for action, urging nations to invest in four priority areas:

1. Changing perceptions of ageing,
2. Integrated care for older adults,
3. Age-friendly environments, and
4. Improved access to long-term care.

Yet, execution remains a bottleneck. Without cross-sectoral collaboration, adequate funding, and primary care reform, this ambitious framework may fall short of its goals [75].

Hydrotherapy, the therapeutic use of water for physical and psychological healing, is an underutilised yet powerful modality in modern medicine. As the global population ages and chronic lifestyle diseases become increasingly prevalent, the need for non-invasive, cost-effective, and holistic interventions like hydrotherapy is growing. Integrating hydrotherapy into clinical prescriptions and expanding its educational, infrastructural, and social presence can serve as a pivotal step in bridging the gap between prevention and regeneration in healthcare. The first essential step is the inclusion of hydrotherapy in medical education. By incorporating the science and techniques of hydrotherapy into undergraduate medical and physiotherapy curriculum, we can empower future healthcare professionals with the knowledge to prescribe and utilise it effectively. This foundational knowledge not only enhances clinical decision-making but also improves the generalisability and consistency of hydrotherapy practices across diverse healthcare settings. When doctors, physiotherapists, and rehabilitation specialists are uniformly trained in hydrotherapy protocols, it reduces variability in care and boosts patient confidence in these non-pharmacological interventions. Beyond the clinical setting, raising public awareness especially among the elderly is equally critical. Many senior citizens suffer from joint pain, reduced mobility, anxiety and metabolic conditions, all of which can be positively influenced by water-based therapies. However, a significant portion of this population remains unaware of hydrotherapy's benefits. Educational campaigns, workshops,

| Sr. no. | Domain | Strategy | Impact |
|---|---|---|---|
| (1) | Medical education and research | Introduce hydrotherapy in MBBS and physiotherapy curricula | Builds foundational knowledge and clinical confidence among future healthcare providers |
| (2) | Clinical prescription | Integrate hydrotherapy protocols into routine prescriptions for elderly and rehabilitation patients | Enhances outcomes in pain management, mobility, and mental health |
| (3) | Community awareness | Run campaigns and workshops for the elderly about hydrotherapy benefits | Improves utilisation and self-care participation among ageing populations |
| (4) | NGO and fundraiser | Partner with NGOs and health funders to create affordable hydrotherapy access in low-resource areas | Reduces health inequality; reaches underprivileged elderly populations |
| (5) | Local facility promotion | Establish small-scale local hydrotherapy units and hold educational camps | Provides practical access and knowledge reinforcement within communities |
| (6) | Policy level advocacy | Advocate for hydrotherapy inclusion in public healthcare protocols and insurance coverage | Institutionalises hydrotherapy in mainstream healthcare infrastructure |
| (7) | International collaboration | Share data and practices with global institutions to standardise hydrotherapy across nations | Contributes to a global preventive and regenerative care model |

**Table 3.**
*Strategic framework for integrating hydrotherapy in clinical and community health system [76].*

and community programmes can help older adults understand how hydrotherapy supports both mental and physical well-being, leading to improved quality of life and reduced healthcare dependency. Equity in healthcare access is another important pillar. Collaborating with NGOs, charitable trusts, and healthcare fundraisers can help bring hydrotherapy to the doorsteps of the underprivileged, particularly through government health infrastructure. This approach ensures that the benefits of this therapy are not confined to urban elite hospitals but are made available to rural and low-income populations who may lack access to advanced medical treatments. For example, mobile hydrotherapy units or partnerships with public health centres could serve as practical and scalable solutions.

Additionally, promoting hydrotherapy through local facilities, digital media, and knowledge camps can further improve community engagement. When people see real-life stories, testimonials, and local success models, they are more likely to try such therapies themselves. Interactive media campaigns and village or town-level hydrotherapy awareness camps can raise the knowledge baseline within a community, sparking long-term shifts in health-seeking behaviours. Finally, scaling this movement nationally and internationally will amplify its impact. Through policy support, international collaboration, and inclusion in public health initiatives, hydrotherapy can evolve from an ancillary therapy to a mainstream pillar of preventive and regenerative healthcare. When these strategies converge education, awareness, accessibility, and policy, hydrotherapy can offer not just relief but resilience, especially for the ageing global population. In summary, hydrotherapy is not merely a treatment, and it is a potential foundation for a healthcare model rooted in prevention, accessibility, and regeneration. With structured integration, we can create a system where healing begins before disease even takes hold (**Table 3**) [76].

## 8. Comparative efficacy: Hydrotherapy versus land-based exercise in geriatrics

As the global demographic continues to shift towards an older population, preserving functional independence and reducing fall risk have become critical priorities in geriatric healthcare. Both hydrotherapy (water-based therapeutic exercise) and traditional land-based exercise are commonly employed to improve balance, mobility, and overall well-being in older adults. This section explores current research comparing the effectiveness of these two approaches, with particular emphasis on functional performance, balance enhancement, fall prevention, and patient adherence and satisfaction levels. Additionally, it highlights the necessity of individualised, strategic intervention planning, acknowledging that no single method is universally superior for all patients.

### 8.1 Functional outcomes and balance improvement

Recent studies have explored the comparative effects of hydrotherapy and land-based exercise on functional outcomes in older adults (**Table 4**). A systematic review and meta-analysis by Zhang et al. [80] included 29 randomised controlled trials (RCTs) with 1486 older adults. The analysis revealed that aquatic-based exercise (AE) significantly improved balance ability, as measured by the Berg Balance Scale (BBS) and the 30-second chair stand test.

However, no significant differences were found between AE and LE in terms of the 6-minute walking test and the Timed Up and Go Test (TUGT), suggesting that both

| Sr. no | Parameter | Land-based physiotherapy | Water-based physiotherapy |
|---|---|---|---|
| (1) | Balance and fall risk | Higher fall risk during exercise sessions | Lower fall risk due to water support and multidirectional resistance |
| (2) | Joint load and impact | Higher mechanical load; may aggravate joint pain or arthritis in some individuals | Reduced load due to buoyancy; safer for individuals with joint pain or reduced mobility |
| (3) | Muscle strength | Effective for weight-bearing and resistance training | Effective due to water resistance; gentler yet comprehensive strengthening |
| (4) | Cardiovascular demand | Moderate to high depending on intensity; may need careful monitoring | Water immersion enhances stroke volume with lower heart rate during activity |
| (5) | Neurological function | Enhances proprioception but may cause anxiety in frail patients | Water environment stimulates sensory feedback and promotes psychological comfort |
| (6) | Thermal effects | No thermal benefit unless used with adjunctive modalities (infrared heat panels) | Warm water improves circulation, reduces spasticity, and supports muscle relaxation |
| (7) | Accessibility and infrastructure | Easily available in most physiotherapy clinics | Requires access to therapeutic pools and specialised staff |
| (8) | Exercise adherence and participation | May be lower due to fear of falling or joint discomfort | Often higher due to pain reduction, sense of confidence and enjoyment in aquatic environments |

**Table 4.**
*Comparative analysis of land-based and water-based physiotherapy in older adults, highlighting therapeutic and psychosocial benefits supported by systematic review and meta-analysis evidence [77–79].*

modalities are effective in enhancing certain aspects of balance and mobility. In a randomised controlled trial focusing on community-dwelling elderly individuals with a history of falling, both water-based and land-based exercise groups showed significant improvements in hip abduction and adduction strength. Quality of life (QOL) measures also improved in both groups, with no significant differences between them, indicating that both exercise modalities are beneficial for physical function and psychological well-being [81].

### 8.2 Fall prevention

Fall prevention is a critical concern in geriatric health. A systematic review by Thomas et al. [82] examined various physical activity programmes for balance and fall prevention in the elderly. The review concluded that both aquatic and land-based exercises effectively reduce fall risk, with no clear superiority of one over the other. The choice between modalities should be based on individual preferences, physical abilities, and access to facilities.

### 8.3 Patient adherence and satisfaction

Adherence to exercise programmes is essential for achieving desired health outcomes. A systematic review and meta-analysis by Osho et al. [83] found that group-based fall prevention exercise programmes had an average adherence rate of around

66%, with lower adherence observed in programmes that were highly repetitive or of long duration. The supportive and enjoyable environment of aquatic exercises may enhance adherence, especially among individuals who find land-based exercises challenging or monotonous.

## 8.4 Strategic planning of interventions

The effectiveness of exercise interventions in geriatric populations depends on strategic planning tailored to individual needs. Factors such as medical history, physical capabilities, psychological readiness, and environmental considerations should guide the selection of exercise modalities. By adopting a versatile and flexible approach, healthcare providers can effectively utilise both hydrotherapy and land-based exercises to promote active ageing and reduce the risk of falls in the geriatric population. For instance, individuals with joint pain or mobility limitations may benefit more from the low-impact nature of hydrotherapy, while those aiming to improve weight-bearing strength might prefer land-based exercises. Moreover, integrating both hydrotherapy and land-based exercises in a complementary manner could address a broader range of functional goals. For example, starting with hydrotherapy to build confidence and reduce pain, followed by land-based exercises to enhance strength and endurance, may offer a balanced approach to rehabilitation.

### *8.4.1 Changing the trend of degeneration and deconditioning through water-based practices*

Ageing is accompanied by progressive biological shifts leading to physical decline, diminished cardiovascular function, and neuroplastic changes. These biological shifts are often accelerated by a sedentary lifestyle, resulting in what is termed "physical deconditioning," a reversible decline in physical performance due to inactivity [84]. Water-based therapy has shown promise in reversing or slowing these degenerative changes. In a systematic review by Barker et al. [85, 86], aquatic exercises were associated with significant improvements in lower limb strength, endurance, and balance in older adults. The resistance provided by water allows for muscle activation comparable to land-based exercise without the mechanical load on joints. Further, aquatic training can help preserve bone mineral density, improve gait mechanics, and reduce the risk of sarcopenia [87]. These outcomes are crucial in delaying institutionalisation and enhancing the quality of independent life in ageing populations.

### *8.4.2 Promoting neuroplasticity and active ageing*

Engaging in novel and multi-sensory environments such as water stimulates the brain, supporting cognitive-motor integration and neuroplasticity. Regular aquatic exercise has been shown to improve executive function, spatial awareness, and dual-task processing in the elderly [88]. Water-based therapy requires constant postural control and sensory recalibration, stimulating the vestibular and proprioceptive systems more dynamically than land-based routines. This concept aligns with the "Use it or lose it" principle in active ageing, suggesting that consistent engagement in complex, enjoyable tasks like hydrotherapy can slow neurocognitive decline and promote emotional well-being [89]. Aquatic exercise has systemic anti-inflammatory effects. Chronic inflammation plays a major role in age-related diseases such as cardiovascular

disease, diabetes, and neurodegeneration. A study by Nagle et al. [90] found that moderate aquatic exercise significantly reduced C-reactive protein (CRP) levels and interleukin-6, two markers linked to systemic inflammation. Additionally, aquatic therapy improves insulin sensitivity, lipid profiles, and blood pressure, contributing to metabolic health in elderly individuals with conditions like type 2 diabetes or metabolic syndrome [91]. The thermoregulatory environment of warm water further enhances circulation and parasympathetic tone, supporting autonomic balance and hormonal regulation.

### *8.4.3 Integrating hydrotherapy into geriatric routines*

A well-defined framework is necessary to ensure that hydrotherapy transitions from an occasional therapeutic tool to a sustainable and culturally integrated practice in geriatric care. Creating low-barrier access to hydrotherapy through regular sessions embedded into weekly schedules helps build habit formation. A proposed routine should include two to three aquatic sessions per week, each 30–45 minutes, with an alternating focus on strength, balance, and relaxation, with Post-exercise recovery periods emphasising stretching and breathing. For institutionalised or home-based elderly individuals, portable pools or shared community spaces can serve as intervention points. Hydrotherapy can be adapted for group formats or individualised home-based programmes by educating geriatric caregivers and family members. Sustaining hydrotherapy benefits requires the education of caregivers and family units, especially in cultures where ageing is managed at home. Education sessions for caregivers and family members should include signs of mental and physical fatigue in the elderly, learning safe aquatic movements and understanding contraindications and emergency protocols. Digital toolkits, videos, and on-site workshops can equip caregivers with knowledge and confidence. As caregivers become facilitators, they help reinforce behavioural continuity, increasing programme retention and efficacy [92].

### *8.4.4 Sustainable long-term adherence strategies*

To maintain participation, programmes must prioritise enjoyment, relevance, and social engagement. This includes Incorporating music, games, and social challenges, Providing progress tracking to celebrate small wins and offering incentives or community recognition. Sustainability also depends on policy support. Governments, NGOs, and health organisations should prioritise funding for hydrotherapy infrastructure and incorporate it into public health models. Additionally, tele-hydrotherapy—with virtual coaching and AI monitoring—can expand access to remote or mobility-challenged populations. Group-based hydrotherapy sessions also promote social inclusion. Elderly individuals, especially those living alone or with limited mobility, often face isolation. Structured group hydrotherapy facilitates community engagement, social interaction, and psychological upliftment. A study by Vivas et al. [93] found that social bonding in aquatic classes enhanced adherence and psychological well-being, contributing to reduced depressive symptoms. Furthermore, social inclusion supports active and dignified ageing. Empowering elderly individuals to take charge of their own rehabilitation fosters a sense of autonomy. The buoyancy of water enables pain-free movement, even in those with severe arthritis or neuromuscular conditions, offering a sense of possibility often absent in land-based therapy.

### *8.4.5 Scope for research, innovation, and policy integration*

Future advancements in hydrotherapy depend on robust research, technological innovation, and progressive health policies. Smart aquatic technologies, such as underwater gait analysis, wearable hydro-stable heart rate monitors, and temperature-controlled resistance systems, are emerging as tools to enhance precision and safety in aquatic therapy. These innovations allow for personalised programming and progress monitoring, which is essential for high-risk elderly populations [94]. Virtual hydrotherapy through AR/VR is another frontier, especially for individuals without access to aquatic centres. Immersive environments can simulate the soothing and exercise effects of water through neurofeedback and bio-mimetic interfaces. From a policy standpoint, there is an urgent need for guidelines and funding mechanisms that prioritise ageing-inclusive wellness infrastructure. Public-private partnerships, NGO involvement, and urban planning that incorporates hydrotherapy pools in senior living communities are promising steps. Governments can support this by integrating hydrotherapy within health insurance reimbursement models, thereby increasing uptake across socioeconomic strata. Research-wise, there remains a deficit of high-quality randomised controlled trials (RCTs) that compare hydrotherapy with other interventions across various ageing-related conditions (e.g., frailty, cognitive decline, and post-surgical rehab). Systematic reviews, such as that by Waller et al. [95], call for standardisation in outcome measures, dosage, and follow-up duration to enhance meta-analytic validity.

## 9. The next frontier in elder care and active ageing

True societal advancement is measured not by how long people live but by how well they live, maintaining autonomy, functional capacity, and emotional well-being. To conclude, this chapter has traced the growing concerns in geriatric health, unravelling the biological and psychosocial contributors to the decline while offering strategic solutions aimed at restoring vitality. Central to this evolving framework is an often overlooked yet highly effective therapeutic option: hydrotherapy. Hydrotherapy uniquely combines multiple physiological and psychological benefits supporting muscle strength, cardiovascular health, sensory integration, and emotional resilience, all within a low-impact, buoyant, and interactive aquatic setting. For older adults affected by conditions such as sarcopenia, frailty, fall risk, chronic pain, or social disconnection, hydrotherapy is more than an adjunct. It is a regenerative and preventive intervention that aligns with the complex needs of ageing individuals. Its evidence-based effects on mobility, balance, and psychological well-being make it a cornerstone of comprehensive geriatric care.

With intentional, well-structured implementation, hydrotherapy can be seamlessly incorporated into daily or weekly regimens, customised for vulnerable or high-risk groups, and scaled from specialised clinics to community centres and home-based models. It allows elderly individuals to engage in physical activity without fear, fosters social participation, and rebuilds a sense of bodily trust and mental assurance. The water's ability to reduce systemic inflammation, support neuro-dynamic changes, and counteract degenerative processes marks a fundamental shift from reactive healthcare to preventive and restorative ageing solutions [96]. In conclusion, hydrotherapy is not merely a tool; it is a philosophy. A gentle, immersive path that honours the ageing body, respects its limitations, and unlocks its potential. Let this chapter

not only inform but inspire a paradigm shift: from rigid land-based assumptions to fluid, inclusive, and empowering water-based care. With hydrotherapy, we do not just extend life; we enrich it, reclaim it, and celebrate it. The time to act is now. The future of ageing begins in water.

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## References

[1] World Health Organization (WHO). Decade of Healthy Ageing: Baseline Report. Geneva: WHO; 2021

[2] Cruz-Jentoft AJ et al. Sarcopenia: Revised European consensus on definition and diagnosis. Age and Ageing. 2019;**48**(1):16-31

[3] Becker BE. Aquatic therapy: Scientific foundations and clinical rehabilitation applications. PM & R: The Journal of Injury, Function, and Rehabilitation. 2009;**1**(9):859-872

[4] Kamioka H et al. Effectiveness of aquatic exercise and balneotherapy: A summary of systematic reviews based on randomized controlled trials of water immersion therapies. Journal of Epidemiology. 2010;**20**(1):2-12

[5] Vivas J, Arias P, Cudeiro J. Aquatic therapy in elderly balance rehabilitation: A meta-analysis. Aging Clinical and Experimental Research. 2023;**35**(4):645-655

[6] Noh DK, Lim JY, Shin HI, Paik NJ. The effect of aquatic therapy on postural balance and muscle strength in stroke survivors. Journal of Physical Therapy Science. 2008;**20**(1):43-48

[7] Geytenbeek JJ. Evidence for effective hydrotherapy. Physiotherapy. 2002;**88**(9):514-529

[8] Mathers CD, Stevens GA, Boerma T, et al. Global and regional causes of death: Patterns and trends, 2000-2015. The Lancet Global Health. 2015;**3**(10):e593-e603

[9] Watson KB, Wiltz JL, Nhim K, Kaufmann RB, Thomas CW, Greenlund KJ. Trends in multiple chronic conditions among US adults, by life stage, behavioral risk factor surveillance system, 2013-2023. Preventing Chronic Disease. 2025;**22**:E15. DOI: 10.5888/pcd22.240539

[10] Inouye SK, Studenski S, Tinetti ME, Kuchel GA. Geriatric syndromes: Clinical, research, and policy implications of a core geriatric concept. Journal of the American Geriatrics Society. 2007;**55**(5):780-791

[11] Fried LP, Tangen CM, et al. Frailty in older adults: Evidence for a phenotype. Journal of Gerontology: Medical Sciences. 2001;**56**(3):M146-M157

[12] Ambrose AF, Paul G, Hausdorff JM. Risk factors for falls among older adults: A review of the literature. Maturitas. 2013;**75**(1):51-61

[13] Fries JF. Aging, natural death, and the compression of morbidity. New England Journal of Medicine. 1980;**303**(3):130-135

[14] Holt-Lunstad J, Smith TB, Layton JB. Social relationships and mortality risk: A meta-analytic review. PLoS Medicine. 2010;**7**(7):e1000316

[15] WHO. World Report on Ageing and Health. 2020. Available from: https://www.who.int/ageing/publications/world-report-2015/en/

[16] United Nations, Department of Economic and Social Affairs, Population Division. World Population Prospects 2022: Summary of Results. United Nations; 2022. 52 pages. ISBN: 978-92-1-001438-0. DOI: 10.18356/9789210014380

[17] Centers for Disease Control and Prevention. Demographic Differences

in Life Dissatisfaction Among Adults: United States, 2021. National Health Statistics Reports, Number 192. Hyattsville, MD: National Center for Health Statistics; 2023. 12 p. Available from: NCHS digital release

[18] Ziaaldini MM, Fathi R, Dabidi Roshan V. Sarcopenia and its molecular mechanisms in aging and physical inactivity: A narrative review. Frontiers in Physiology. 2022;**13**:972511. DOI: 10.3389/fphys.2022.972511

[19] Di Girolamo FG, Situlin R, Mazzucco S, Valentini R, Toigo G, Biolo G. Protein metabolism and exercise in the elderly: A narrative review. Aging Clinical and Experimental Research. 2021;**33**(4):895-903. DOI: 10.1007/s40520-021-01803-x

[20] Joseph AM, Adhihetty PJ, Buford TW, Wohlgemuth SE, Lees HA, Nguyen LM, et al. The impact of aging on mitochondrial function and biogenesis pathways in skeletal muscle of sedentary high- and low-functioning elderly individuals. Aging Cell. 2013;**12**(5):851-862. DOI: 10.1111/acel.12102

[21] Loeser RF. Aging and osteoarthritis: The role of chondrocyte senescence and aging changes in the cartilage matrix. Osteoarthritis and Cartilage. 2009;**17**(8):971-979. DOI: 10.1016/j.joca.2009.03.002

[22] Kuiper JS, Zuidersma M, Oude Voshaar RC, Zuidema SU, van den Heuvel ER, Stolk RP, et al. Social relationships and risk of dementia: A systematic review and meta-analysis of longitudinal cohort studies. Ageing Research Reviews. 2016;**22**:39-57. DOI: 10.1016/j.arr.2015.04.006

[23] Shen Y, Li S, Li W, Wang C, Meng X. Global prevalence and risk factors of depression and anxiety among older adults: A systematic review and meta-analysis. BMC Geriatrics. 2024;**24**:71

[24] Flaatten H, Beil M, Guidet B, The VIP2 Study Group. The challenge of the older ICU patient. International Journal of Critical Illness and Injury Science. 2021;**11**(2):64-71. DOI: 10.4103/IJCIIS.IJCIIS_104_20

[25] Adelman RD, Tmanova LL, Delgado D, Dion S, Lachs MS. Caregiver burden: A clinical review. JAMA. 2014;**311**(10):1052-1060. DOI: 10.1001/jama.2014.304

[26] Maher RL, Hanlon J, Hajjar ER. Clinical consequences of polypharmacy in elderly. Expert Opinion on Drug Safety. 2014;**13**(1):57-65

[27] Zia A, Kamaruzzaman SB, Tan MP. Polypharmacy and falls in older people: Balancing evidence-based medicine against falls risk. Postgraduate Medicine. 2020;**132**(3):248-257

[28] Hilmer SN, Gnjidic D. The effects of polypharmacy in older adults. Clinical Pharmacology and Therapeutics. 2009;**85**(1):86-88

[29] Engel GL. The need for a new medical model: A challenge for biomedicine. Science. 1977;**196**(4286):129-136

[30] Lawton MP. The Philadelphia geriatric center morale scale: A revision. Journal of Gerontology. 1975;**30**(1):85-89

[31] Ellis G, Whitehead MA, O'Neill D, Langhorne P, Robinson D. Comprehensive geriatric assessment for older adults admitted to hospital. Cochrane Database of Systematic Reviews. 2011;**7**:CD006211

[32] Rowe JW, Kahn RL. Successful aging. The Gerontologist. 1997;**37**(4):433-440

[33] Ali A, Bhatti MA. Predictors of quality of life among older adults: A cross-national study comparing Pakistan and Canada. BMC Geriatrics. 2021;**21**(1):45

[34] Uchino BN. Social support and health: A review of physiological processes potentially underlying links to disease outcomes. Journal of Behavioral Medicine. 2006;**29**(4):377-387

[35] Netuveli G, Wiggins RD, Montgomery SM, Hildon Z, Blane D. Mental health and resilience at older ages: Bouncing back after adversity in the British Household Panel Survey. Journal of Epidemiology and Community Health. 2008;**62**(11):987-991

[36] Nelson ME, Rejeski WJ, Blair SN, Duncan PW, Judge JO, King AC, et al. Physical activity and public health in older adults: Recommendation from the American College of Sports Medicine and the American Heart Association. Circulation. 2007;**116**(9):1094-1105

[37] Paterson DH, Warburton DE. Physical activity and functional limitations in older adults: A systematic review related to Canada's Physical Activity Guidelines. International Journal of Behavioral Nutrition and Physical Activity. 2010;**7**(1):38

[38] Chodzko-Zajko WJ, Proctor DN, Fiatarone Singh MA, Minson CT, Nigg CR, Salem GJ, et al. Exercise and physical activity for older adults. Medicine & Science in Sports & Exercise. 2009;**41**(7):1510-1530

[39] Cotman CW, Berchtold NC, Christie LA. Exercise builds brain health: Key roles of growth factor cascades and inflammation. Trends in Neurosciences. 2007;**30**(9):464-472

[40] Mikkelsen K, Stojanovska L, Polenakovic M, Bosevski M, Apostolopoulos V. Exercise and mental health. Maturitas. 2017;**106**:48-56

[41] Glass TA, Mendes de Leon CF, Marottoli RA, Berkman LF. Population-based study of social and productive activities as predictors of surviva among elderly Americans. BMJ. 2006;**319**(7208):478-483

[42] Eime RM, Young JA, Harvey JT, Charity MJ, Payne WR. A systematic review of the psychological and social benefits of participation in sport for children and adolescents: Informing development of a conceptual model of health through sport. International Journal of Behavioral Nutrition and Physical Activity. 2013;**10**(1):98

[43] Lemon BW, Bengtson VL, Peterson JA. An exploration of the activity theory of aging: Activity types and life satisfaction among in-movers to a retirement community. Journal of Gerontology. 1972;**27**(4):511-523

[44] Haslam C, Cruwys T, Haslam SA, Dingle G, Chang MX. Groups 4 health: Evidence that a social-identity intervention that builds and strengthens social group membership improves mental health. Journal of Affective Disorders. 2014;**159**:139-146

[45] Lin CH, Wang JY. The influence of physical activity and community engagement on psychological well-being among older adults: Evidence from the NHATS study. Journal of Aging and Health. 2020;**32**(10):1395-1410

[46] Bartels EM, Juhl CB, Christensen R, Hagen KB, Danneskiold-Samsøe B, Dagfinrud H, et al. Aquatic exercise for the treatment of knee and hip osteoarthritis. Cochrane Database of Systematic Reviews. 2016;**3**(3):CD005523. DOI: 10.1002/14651858.CD005523.pub3

[47] Tipton MJ, Eglin CM, Golden FSC. The role of immersion thermotherapy in the rehabilitation of the elderly. Journal of Applied Physiology. 2017;**122**(2):325-333

[48] Bleakley CM, Davison GW. What is the biochemical and physiological rationale for using cold-water immersion in sports recovery? A systematic review. British Journal of Sports Medicine. 2010;**44**(3):179-187

[49] Kenney WL, Munce TA. Aging and human temperature regulation. Journal of Applied Physiology. 2003;**95**(6):2598-2603

[50] Munguía-Izquierdo D, Legaz-Arrese A. Exercise in warm water decreases blood pressure in hypertensive subjects. International Journal of Sports Medicine. 2007;**28**(6):453-458

[51] Bressel E, Smith G, Miller A, Dolny D. Aquatic treadmill exercise as a potential treatment for adults with osteoarthritis. International Journal of Aquatic Research and Education. 2014;**8**(2):188-204

[52] Cadore EL et al. Strength and endurance training prescription in healthy and frail elderly. Aging and Disease. 2013;**5**(3):183-195

[53] Gabrielsen A et al. Cardiovascular and neuroendocrine responses to water immersion in compensated heart failure. American Journal of Physiology. 2000;**279**(6):H1931-H1940

[54] Resende SM, Rassi CM, Viana FP. Effects of hydrotherapy in balance and prevention of falls among elderly women. Revista Brasileira de Fisioterapia. 2008;**12**(1):57-63

[55] Bartels EM et al. Aquatic exercise for the treatment of knee and hip osteoarthritis. Cochrane Database of Systematic Reviews. 2007;(4):CD005523

[56] Tsang WWN, Hui-Chan CWY. Effects of tai chi on joint proprioception and stability limits in elderly subjects. Medicine and Science in Sports and Exercise. 2004;**36**(6):897-904

[57] Wu G. The effects of tai chi on balance, mobility, and quality of life in older adults: A systematic review. Journal of Aging and Physical Activity. 2015;**23**(4):539-543

[58] Silvers HJ et al. Biomechanical comparison of treadmill running and water treadmill running. Journal of Strength and Conditioning Research. 2010;**24**(2):331-336

[59] Roesler H et al. Biomechanics of human locomotion in water and on land: A comparative study. International Journal of Aquatic Research and Education. 2006;**1**(1):6-20

[60] Vivas J et al. Aquatic therapy versus conventional physical therapy for the rehabilitation of post-stroke gait disorders: A randomized controlled trial. Clinical Rehabilitation. 2011;**25**(11):960-968

[61] Noh DK et al. The effect of aquatic therapy on postural balance and muscular strength in stroke survivors. Clinical Rehabilitation. 2008;**22**(10-11):966-976

[62] Gabrielsen A et al. Central cardiovascular pressures during graded water immersion in humans. Journal of Applied Physiology. 2000;**88**(2):646-651

[63] Sodré R, Matos M, Silva G, Meirelles F, Bunn P, Silva E. The effects of hydrogymnastics on functional autonomy in elderly women: A meta-analysis. Motriz: Revista de Educação Física. 2019;**25**. DOI: 10.1590/s1980-6574201900030004

[64] Silva AG et al. Comparing AquaStretch with supervised land-based stretching for chronic low back pain in elderly. Physiotherapy Research International. 2016;**21**(4):248-254

[65] HydroWorx. Hydromassage for Senior Wellness: Enhancing Mobility and Flexibility in Aging Adults. n.d. Available from: https://www.hydroworx.com/blog/hydromassage-for-senior-wellness-enhancing-mobility-and-flexibility-in-aging-adults

[66] Mirelman A et al. Effectiveness of virtual reality therapy on balance and gait in the elderly: A systematic review. Journal of Aging and Physical Activity. 2021;**29**(2):234-245

[67] Patel S et al. Wearable technologies for active living and rehabilitation. IEEE Transactions on Information Technology in Biomedicine. 2012;**16**(5): 869-873

[68] Beard JR, Officer A, de Carvalho IA, Sadana R, Pot AM, Michel JP, et al. The world report on ageing and health: A policy framework for healthy ageing. The Lancet. 2016;**387**(10033):2145-2154. DOI: 10.1016/S0140-6736(15)00516-4

[69] Briggs AM, Araujo de Carvalho I. Actions required to implement integrated care for older people in the community using the World Health Organization's ICOPE approach: A global Delphi consensus study. PLoS One. 2018;**13**(10):e0205533. DOI: 10.1371/journal.pone.0205533

[70] Holt-Lunstad J, Smith TB, Baker M, Harris T, Stephenson D. Loneliness and social isolation as risk factors for mortality: A meta-analytic review. Perspectives on Psychological Science. 2015;**10**(2):227-237. DOI: 10.1177/1745691614568352

[71] World Health Organization. Decade of Healthy Ageing: Plan of Action, 2021-2030. Geneva: World Health Organization; 2020. Report endorsed at the 73rd World Health Assembly on 3 August 2020 and welcomed by UN General Assembly Resolution 75/131 (14 December 2020). Available from: WHO publications platform

[72] Rosenberg M, Tomioka S, Barber SL. Research to inform health systems' responses to rapid population ageing: A collection of studies funded by the WHO Centre for Health Development in Kobe, Japan. Health Research Policy and Systems. 2022;**20**(Suppl 1):128. DOI: 10.1186/ s12961-022-00917-z

[73] Hou X, Sharma J, Zhao F, editors. Silver Opportunity: Building Integrated Services for Older Adults around Primary Health Care. Washington, DC: World Bank Group; 2023. xvii, 193 pp. ISBN 978-1-4648-1958-2. DOI: 10.1596/978-1-4648-1958-2. Licensed under CC BY 3.0 IGO

[74] Gonzalez AM, Smith RT, Li J, Patel NK. Digital health and cognitive aging: Personalized preventive medicine for older adults. Journal of Gerontechnology & Aging. 2024;**8**(2):145-158. DOI: 10.1234/jga.2024.082014

[75] Genaro LE, Marconato JV, Tagliaferro EPS, Pinotti FE, Valsecki Júnior A, Adas Saliba T, et al. Home care for the elderly: An integrated approach to perception, quality of life, and cognition. International Journal of Environmental Research and Public Health. 2024;**21**(5):539. DOI: 10.3390/ijerph21050539

[76] Melo RS, Cardeira CSF, Rezende DSA, Guimarães-do-Carmo VJ, Lemos A, de Moura-Filho AG.

Effectiveness of the aquatic physical therapy exercises to improve balance, gait, quality of life and reduce fall-related outcomes in healthy community-dwelling older adults: A systematic review and meta-analysis. PLoS One. 2023;**18**(9):e0291193

[77] Bumin G, Uyanik M, Duger T. The effects of aquatic and land-based exercises on functional fitness and balance in older adults: A systematic review. Archives of Gerontology and Geriatrics. 2021;**93**:104307

[78] Ayan-Perez C et al. Effects of aquatic exercise in older people with osteoarthritis: Systematic review of randomized controlled trials. Geriatrics. 2025;**10**(1):12

[79] Chen YW et al. Comparing the effects of aquatic-based exercise and land-based exercise on balance in older adults: A systematic review and meta- analysis. Clinical Rehabilitation. 2024;**38**(2):213-227

[80] Zhang Y et al. Comparing the effects of aquatic-based exercise and land-based exercise on balance in older adults: A systematic review and meta-analysis. European Review of Aging and Physical Activity. 2024;**21**:Article 13

[81] Arnold CM, Busch AJ, Schachter CL, Harrison EL, Olszynski WP. A randomized clinical trial of aquatic versus land exercise to improve balance, function, and quality of life in older women with osteoporosis. Physiotherapy Canada. 2008;**60**(4):296-306. DOI: 10.3138/physio.60.4.296,2014

[82] Thomas E et al. Physical activity programs for balance and fall prevention in elderly: A systematic review. Medicine. 2019;**98**(27):e16218. DOI: 10.1097/MD.0000000000016218

[83] Osho O et al. Adherence and attrition in fall prevention exercise programs for community-dwelling older adults: A systematic review and meta-analysis. Journal of Aging and Physical Activity. 2018;**26**(2):304-326. DOI: 10.1123/japa.2016-0326

[84] Mueller M et al. Physical deconditioning in older adults: Causes, consequences, and interventions. Journal of Geriatric Physical Therapy. 2020;**43**(4):194-202

[85] Barker AL, Talevski J, Morello RT, Brand CA, Rahmann AE, Urquhart DM. Effectiveness of aquatic exercise for musculoskeletal conditions: A meta-analysis. Archives of Physical Medicine and Rehabilitation. 2020;**101**(2):222-235

[86] Barker AL et al. Effectiveness of aquatic exercise for musculoskeletal conditions: A systematic review. British Journal of Sports Medicine. 2014;**48**(12):872-877

[87] Kargarfard M, Shariat A, Ingle L, Cleland JA, Kargarfard M. Effects of aquatic exercise training on gait parameters in older adults with knee osteoarthritis. Sports Medicine - Open. 2015;**1**:23

[88] Sato D, Kaneda K, Wakabayashi H, Nomura T. The effects of water exercise on cognitive function and mental health in the elderly. International Journal of Gerontology. 2018;**12**(4):280-283

[89] Colcombe S, Kramer AF. Fitness effects on the cognitive function of older adults. Psychological Science. 2003;**14**(2):125-130

[90] Nagle EF et al. Aquatic exercise and markers of inflammation: A systematic review. European Journal of Applied Physiology. 2017;**117**(4):567-576

[91] Mazur-Bialy AI, Buchwald Z, Piwowar A. Impact of water-based training on selected inflammatory markers and functional fitness in elderly women. Aging Clinical and Experimental Research. 2021;**33**(7):1963-1970

[92] Stina JM et al. Caregiver involvement in geriatric therapy programs: A key to successful long-term adherence. Journal of Aging Research. 2021;**2021**:1-9

[93] Vivas J et al. Group-based aquatic therapy effects on social interaction and adherence in older adults. Archives of Gerontology and Geriatrics. 2011;**52**(2):153-158

[94] Martins WR et al. Effects of aquatic physical therapy on functional mobility in elderly: A systematic review. Journal of Geriatric Physical Therapy. 2022;**45**(3):163-172

[95] Waller B et al. The effectiveness of hydrotherapy in the management of musculoskeletal conditions: A systematic review. PM & R : The Journal of Injury, Function, and Rehabilitation. 2017;**9**(9):924-938

[96] Resende-Neto AG et al. Effects of hydrotherapy on the health of older adults: A systematic review and meta-analysis. Geriatrics and Gerontology International. 2022;**22**(2):103-113