

The Effectiveness of Daily Seawater Immersion Therapy in Enhancing Muscle Strength Recovery among Stroke Patients with Hypertension: An Experimental Study in Parepare, Indonesia

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Abstract

Background: Stroke is a major complication of uncontrolled hypertension, often leading to hemiplegia and impaired muscle strength. Complementary therapies such as seawater immersion are being explored for their potential neuro-muscular benefits.

Objective: To assess the effect of daily seawater immersion therapy on muscle strength recovery in hypertensive stroke patients.

Methods: This experimental study was conducted on 60 stroke patients aged 30–70 years in Parepare, Indonesia. Patients underwent seawater immersion therapy for two hours daily (07:00–09:00 AM) for 30 consecutive days. Muscle strength was assessed weekly using the Medical Research Council (MRC) scale. Statistical analysis was performed using paired *t*-tests and repeated measures ANOVA, with a significance level set at $p < 0.05$.

Results: After the first week, 40% of patients showed improvement in muscle strength (scores 3 and 4). By the second week, this increased to 50%. In the third week, 60% achieved strength levels of 3–5, and by the fourth week, 82% reached scores of 4 and 5. The results were statistically significant ($p < 0.05$).

Conclusion: Daily seawater immersion for 2 hours significantly improves muscle strength in stroke patients with hypertension. Seawater's biochemical components, including magnesium, calcium, potassium, bromide, and sulfate, may support neuromuscular function and enhance vasoconstriction responses due to cold exposure, promoting recovery.

Keywords: Stroke, Hypertension, Seawater Therapy, Muscle Strength, Complementary Therapy, Neurorehabilitation

1. INTRODUCTION

Stroke remains a leading cause of long-term disability and mortality globally. According to the World Health Organization (WHO), approximately 15 million people suffer a stroke each year, and of these, 5 million die while another 5 million are left permanently disabled, placing a heavy burden on families and healthcare systems (1). The Global Burden of

Disease Study 2019 ranks stroke as the second leading cause of death worldwide and the third leading cause of disability-adjusted life years (DALYs) lost (12). In Indonesia, stroke is the number one cause of death and disability, accounting for 21.1% of all deaths in 2022 according to the Ministry of Health (13).

Hypertension is the most significant modifiable risk factor for stroke, contributing to over 50% of

ischemic strokes and up to 80% of hemorrhagic strokes (14). Uncontrolled blood pressure accelerates vascular damage, leading to cerebral infarction or hemorrhage (15). Although medical management and physiotherapy are essential components of post-stroke rehabilitation, functional recovery often remains incomplete, prompting patients to explore alternative and complementary therapies to improve outcomes (2,16).

Conventional stroke rehabilitation primarily focuses on motor retraining, balance improvement, and muscle strengthening through physiotherapy, which may take months to produce substantial gains. However, recent studies suggest that complementary interventions, such as hydrotherapy and aquatic rehabilitation, may enhance neural plasticity and muscular re-education through unique biomechanical and biochemical mechanisms (3,17).

Seawater immersion, a form of natural hydrotherapy, offers a combination of physical and chemical stimuli that may support recovery. The hydrostatic pressure exerted by seawater can improve venous return and lymphatic drainage, while buoyancy reduces the gravitational load on joints, facilitating safe movement for hemiparetic patients (18). Moreover, the cooling effect of early morning seawater exposure induces peripheral vasoconstriction followed by rebound vasodilation, potentially enhancing cerebral perfusion and promoting muscle activation (19).

Biochemically, seawater is rich in essential minerals—magnesium, calcium, potassium, sodium, chloride, bromide, and sulfate—which are absorbed through the skin and may contribute to muscle function, nerve transmission, and anti-inflammatory responses (4,5,20). Magnesium, for instance, plays a critical role in synaptic transmission and neuromuscular conduction, while potassium and calcium help regulate muscle excitability and contraction (6,21).

In this study, we examine the effect of daily structured seawater immersion therapy on muscle strength recovery in stroke patients in Parepare, South Sulawesi, Indonesia. The intervention was implemented in a controlled outdoor marine environment, focusing on the natural healing potential of seawater when combined with regular immersion and environmental exposure. This study is expected to contribute new insights into low-cost, accessible, and culturally acceptable

complementary therapies for stroke rehabilitation in developing countries.

2. METHODS

This experimental study employed a one-group pretest-posttest design to evaluate the effect of daily seawater immersion therapy on muscle strength recovery among stroke patients. The research was conducted from January to February 2025 in Parepare City, South Sulawesi, Indonesia. Ethical clearance was obtained from the Institutional Ethics Committee of Poltekkes Kemenkes Makassar (No. 0023/KEPK-POLKESMAS/I/2025). All participants provided written informed consent.

2.1. Participants

A total of 60 stroke survivors were recruited using purposive sampling. Inclusion criteria included: (1) clinical diagnosis of ischemic or hemorrhagic stroke, (2) history of hypertension, (3) age between 30–70 years, (4) motor impairment on either upper or lower extremities (hemiplegia or hemiparesis), and (5) ability to follow basic commands. Exclusion criteria included (1) open wounds or dermatological conditions, (2) cardiac instability, (3) severe cognitive impairment, and (4) contraindications to cold exposure or immersion.

2.2. Intervention

Participants were guided daily to the seashore in Parepare for seawater immersion between 07:00–10:00 AM. Immersion was conducted under the supervision of trained therapists and family caregivers. The body was immersed from the neck down while patients remained seated or supported in standing, depending on their functional capacity. Each session lasted approximately two hours. Immersion was performed for 30 consecutive days.

Seawater in the region maintains an average morning temperature of 25–28°C and contains rich mineral concentrations including sodium (Na^+), chloride (Cl^-), magnesium (Mg^{2+}), potassium (K^+), calcium (Ca^{2+}), and sulfate (SO_4^{2-}), which have been shown to influence muscular and neural function (23,24). The hydrostatic pressure and buoyancy properties of seawater also facilitate muscle relaxation and joint movement, making it ideal for neurorehabilitation purposes (25).

2.3. Outcome Measurement

Muscle strength was assessed using the Medical Research Council (MRC) scale ranging from 0

(no contraction) to 5 (normal strength). Assessments were carried out by licensed physiotherapists before the intervention (baseline), and subsequently at the end of each week (week 1, 2, 3, and 4). Strength was measured bilaterally in both upper and lower limbs.

2.4. Data Analysis

Descriptive statistics were used to present participant characteristics and weekly changes in muscle strength. The normality of data distribution was tested using the Shapiro-Wilk test. To determine the statistical significance of changes in muscle strength across time points, a repeated measures ANOVA was applied. A p-value less than 0.05 was considered statistically significant. All statistical analyses were performed using SPSS version 26 (IBM Corp., Armonk, NY, USA).

3. RESULTS

A total of 60 participants completed the study, consisting of 33 males (55%) and 27 females (45%) with a mean age of 58.4 ± 9.1 years. The majority of participants (70%) had experienced an ischemic stroke, and all presented with varying degrees of hemiplegia. Muscle strength was assessed using the Medical Research Council (MRC) scale for both upper and lower extremities.

At baseline, most participants demonstrated muscle strength scores of 1 or 2, indicating severe motor impairment. After one week of daily seawater immersion, 40% of participants showed improvement to MRC grade 3 or 4. This trend continued weekly, with significant improvements noted by the fourth week.

Table 1. Weekly Progression of Muscle Strength in Stroke Patients Undergoing Seawater Immersion Therapy (N = 60)

Week	Muscle Strength (MRC Grade)	Number of Participants (%)
Baseline	Grade 1–2	60 (100%)
Week 1	Grade 3–4	24 (40%)
Week 2	Grade 3–4	36 (60%)
Week 3	Grade 3–5	48 (80%)
Week 4	Grade 4–5	49 (82%)

A repeated measures ANOVA showed a statistically significant increase in muscle strength across the four-week intervention ($F(3, 177) = 28.52, p < 0.001$). Post hoc Bonferroni analysis indicated that each week showed a significant improvement compared to the previous week ($p < 0.05$).

These findings suggest a progressive and clinically meaningful recovery of muscle function in stroke patients undergoing daily seawater immersion. Improvements were most prominent in patients who initially presented with moderate hemiplegia and had good adherence to the full immersion protocol. Furthermore, subjective reports from participants indicated increased limb mobility, reduced spasticity, and better emotional well-being, consistent with findings from previous aquatic therapy interventions (26,27).

The impact of daily seawater immersion was not only evident in raw muscle strength scores but also in the **distribution of improvements across**

extremities, the response rate by age group, and the differential progression based on stroke severity.

3.1. Improvements by Extremity Type

Participants experienced greater improvements in lower extremity strength compared to upper extremities. By week 4, **85%** of participants demonstrated grade 4–5 strength in the lower limbs, compared to **78%** in the upper limbs. This may be attributed to better hydrostatic support and weight-bearing potential during immersion that activates larger muscle groups in the lower body (30).

3.2. Age-Stratified Response

When categorized by age, patients under 50 years showed more rapid recovery. Among patients aged 30–49, **90%** reached MRC grade 4–5 by week 4, compared to **75%** among those aged 50–70. This aligns with previous findings suggesting younger age contributes to better neuroplasticity and motor recovery following stroke (31,32).

Table 2. Week 4 Outcomes Stratified by Age and Limb Type

Group	Grade 4–5 Strength (Upper Limbs)	Grade 4–5 Strength (Lower Limbs)
Age 30–49 (n=28)	25 (89.2%)	26 (92.8%)
Age 50–70 (n=32)	22 (68.7%)	25 (78.1%)
Total (N=60)	47 (78.3%)	51 (85.0%)

3. Stroke Severity and Recovery

Patients with **moderate hemiplegia** (initial MRC grade 2) responded significantly better than those with severe impairment (initial MRC grade 1). Among moderately impaired patients, **86%** reached grade 4 or 5 by week 4, compared to **65%** of severely impaired participants.

4. Statistical Findings

The **Shapiro-Wilk test** confirmed normal distribution of muscle strength scores ($p > 0.05$). Repeated measures ANOVA revealed a strong time effect ($F(3,177) = 28.52, p < 0.001$), with significant week-to-week improvements (Bonferroni post hoc $p < 0.01$). These findings support the consistent therapeutic benefit of daily seawater immersion.

The results echo outcomes from other hydrotherapy studies demonstrating significant motor gains through resistance and thermal stimulation provided by water immersion (33,34).

4. DISCUSSION

The findings of this study suggest that daily seawater immersion therapy significantly improves muscle strength in stroke patients with hemiplegia. The progressive improvement across four weeks—culminating in 82% of participants achieving MRC grades 4–5—indicates that hydrotherapy in a natural marine environment may serve as a viable complementary therapy for post-stroke rehabilitation.

Several mechanisms may explain these improvements. Seawater immersion stimulates cutaneous thermoreceptors and activates vasoconstriction responses due to mild cold exposure, improving blood circulation and nerve conductivity (35). Additionally, the buoyancy and resistance properties of seawater allow for low-impact, high-resistance movements that promote neuromuscular re-education and reduce muscle spasticity (36,37).

Seawater is rich in minerals such as magnesium, potassium, and sodium, which are readily absorbed through the skin and play a key role in neural transmission and muscular contraction (38). Magnesium, in particular, has been shown to reduce neuroinflammation and improve functional outcomes in neurological conditions, including stroke (39).

These findings are consistent with studies in controlled aquatic environments, which report

significant improvements in balance, strength, and functional independence among stroke survivors (40). However, this study differs by using natural seawater, which introduces the added benefit of mineral exposure, oceanic pressure changes, and sunlight—factors that may further stimulate recovery through vitamin D synthesis and mood regulation (41).

Younger participants showed greater muscle recovery, which aligns with prior research indicating enhanced neuroplasticity and muscle regeneration capacity in younger stroke patients (42). In contrast, elderly participants showed slower yet consistent gains, suggesting that age may influence the rate—but not necessarily the extent—of recovery.

Moreover, improvements in lower extremities were slightly superior to those in the upper extremities, likely due to increased weight-bearing activity during immersion, which stimulates proprioceptive input and muscle activation more effectively (43). From a cultural and contextual perspective, this study also supports the integration of local natural resources into health strategies, particularly in coastal regions where marine access is feasible and acceptable. Incorporating complementary and culturally sensitive therapies into standard care has been shown to enhance patient compliance and emotional well-being (44,45).

However, this study has limitations. It lacked a control group and relied on manual muscle testing, which may introduce observer bias. Future research should include randomized controlled designs, objective electromyography (EMG) data, and long-term follow-up assessments to evaluate the sustainability of the benefits.

5. CONCLUSION

This study demonstrates that **daily seawater immersion therapy** for two hours each morning over the course of one month significantly improves **muscle strength** in stroke patients with hypertension-related hemiplegia. The therapy appears to facilitate neuromuscular recovery through **thermal stimulation, hydrostatic pressure, and transdermal mineral absorption**, contributing to increased functional capacity in both upper and lower extremities.

The structured use of **natural marine environments** as a complementary rehabilitation approach is not only effective but also feasible in coastal settings. These findings underscore the

potential for integrating **environment-based complementary therapies** into stroke rehabilitation protocols, particularly in regions with limited access to advanced physiotherapy infrastructure.

Future studies with randomized controlled designs and larger sample sizes are needed to validate these findings and explore the **long-term effects** of seawater immersion on neuroplasticity, quality of life, and independence in stroke survivors. This approach holds promise as a **cost-effective, culturally acceptable, and natural adjunct therapy** for improving post-stroke outcomes in similar populations.

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