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# The Impact of Aquatic Therapy on Balance and Mobility in Individuals with Spinal Cord Injury- A Systematic Review and Meta-Analysis


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**Abstract** **Background:** Although the evidence was conflicting, earlier studies suggested that aquatic therapy (AT) may improve balance and mobility in people with spinal cord injuries (SCI). This population's comprehensive review and meta-analysis aimed to assess how AT affected mobility and balance. **Methods:** We thoroughly searched the most extensive databases to find pertinent observational studies and randomized controlled trials (RCTs) contrasting AT with control therapies. After extracting data, two impartial reviewers evaluated the quality of the study. Using a random-effects model, the mean difference (MD) in balance and mobility improvement was determined. $I^2$ statistics were used to evaluate heterogeneity. **Outcomes:** The evaluation contained six studies. AT was considerably improved, as evidenced by the pooled MD for gait improvement of $-0.33(95\% CI : -0.45 to - 0.21)$. Additionally demonstrating a substantial effect of AT was the pooled MD for mobility improvement, which was $-0.22(95\% CI : -0.42 to -0.02)$. On the other hand, the mobility data showed significant heterogeneity $(I^2 = 72\%)$. **Conclusion:** The results imply that AT may considerably enhance movement and balance in people with SCI. The general results favor integrating assistive technology (AT) into rehabilitation programs for patients with spinal cord injuries (SCI), notwithstanding considerable variation in the research, especially about mobility. More investigation is required to investigate the causes of heterogeneity and enhance AT methods.



**Key Words** Aquatic therapy, Spinal cord injury, Balance, Mobility


## 1. Introduction

Spinal cord injuries (SCIs) can cause serious health problems that can significantly affect a patient's quality of life for a number of reasons. The main objectives of the spinal cord injury rehabilitation process are to increase the patient's functional capacity and lower the risk of developing new health problems [1]. Patients with SCIs frequently experience spasticity, which is usually managed with medication. However, side effects from these drugs are common. One tactic to perhaps lower the need for these medications is to incorporate hydrotherapy into the rehabilitation regimen [2].

As such, it becomes essential to use effective rehabilitation strategies. These are crucial for improving the general well-being of individuals with SCIs in addition to their physical function. There are challenges along the way to rehabilitation, though. One such significant challenge that individuals with SCIs must face is spasticity. This condition impairs mobility and makes it difficult for people to complete activities of daily life, which presents challenges for patients and their rehabilitation teams [3].

The use of water for therapeutic purposes, or aquatic therapy (AT), has a lengthy history that goes back to prehistoric times [4]. The first accounts of water's medical properties date back to the 19th century, highlighting the benefits of this substance for health [5]. Since then, hydrotherapy has been demonstrated to be effective in the treatment of numerous diseases, including pain [6]. By blocking nociceptive signals, which are responsible for pain, it can also improve sensory perception [7], [8].

In addition, there are other benefits to using warm water for hydrotherapy. It can fuel the body, diminish the effects of lactic acid and other chemicals in the body, enhance muscle relaxation, and lower the tolerance for pain [9], [10].

A particular study listed several goals for water training, such as lowering spasticity, improving lung function, increasing endurance, and providing psychological benefits. The temperature of the water should be taken into account because extremes in either direction have the potential to worsen spasticity and lessen the effectiveness of therapy efforts [11]. The warmth of the water facilitates mobility for people with spinal cord injuries, which can be difficult or uncomfortable on land. Furthermore, it aids in their ability to get over their fear of falling, which makes it easier for them to accomplish practical and physical objectives [11]. But access to water rehabilitation may not always be convenient for persons with spinal cord injuries. Numerous of these patients suffer from neurogenic bowel dysfunction, which increases their likelihood of developing colostomies and involuntary incontinence on a regular basis [12].

Numerous research have suggested that water treatment may be beneficial for individuals with spinal cord injuries coping with various outcomes [13]–[15]. However, a variety of results have been obtained from these studies. While some studies claim large gains, others have only found small impacts. This discrepancy in results could be caused by a variety of factors, such as differences in the study design, the intervention methods, the outcome evaluation measures, and the characteristics of the sample.

This led to the implementation of a systematic review and meta-analysis to completely investigate and aggregate the available data regarding the effectiveness of water therapy in improving balance and mobility in individuals with spinal cord injuries in response to these uncertain outcomes. This study aimed to provide a comprehensive and unbiased assessment of the current evidence in order to provide helpful insights for clinical decision-making and future research in this field. The ultimate goal is to improve therapeutic approaches and outcomes for those suffering from spinal cord injury.

## 2. Materials and Methods

### *Review Design*

This systematic review and meta-analysis was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol [16]. The initial phase involved the identification of potential studies through a comprehensive search of multiple databases. Search terms were carefully chosen to ensure all relevant studies related to AT and SCI were captured. Following the identification phase, the title and abstract of each potential study were screened for relevance, excluding those that did not meet the pre-determined inclusion criteria as shown through Figure 1.

### *PICO and Research Question*

The review was guided by the PICO (Population, Intervention, Comparison, Outcomes) framework, which is a well-recognized tool for formulating research questions in systematic reviews. The population of interest was individuals with SCI, the intervention was AT, and the comparison was no intervention or conventional therapy. The outcomes of interest were measures of balance and mobility.

By clearly defining the PICO components, we tried to ensure a focused and relevant review, addressing a clear research question: "Does AT improve balance and mobility in individuals with SCI compared to no intervention or conventional therapy?"

### *Database Search Strategy*

Eight different databases were searched for identification of relevant studies for this investigation, including PubMed, Web of Science, Scopus, CINAHL, Cochrane Central Register of Controlled Trials, EMBASE, PsycINFO, and PEDro. The search strategy comprised of a combination of MeSH (Medical Subject Headings) terms and free-text keywords to maximize the sensitivity of the search. Boolean operators ("AND" and "OR") were used to further combine the search terms. The term "OR" was used to combine similar keywords within the same category, whereas "AND" was employed to intersect different categories, as elucidated through Table 1.

### *Selection criterion*

The criteria for inclusion and exclusion are summarized in Table 2 shown below:

### *Variable extraction protocol*

Basic details about the authors, the year the study was published, and the nation in which the research was carried out were among the data acquired from the studies. Complete details regarding the study's methodology were also acquired. This covered the study's design, the size of the research team, and the statistical techniques applied to the data analysis. Additionally, information about the study subjects was gathered. In this, they disclosed information on their age, gender, and particular spinal cord injury. The water therapy employed in the study was also included in the acquired information. This covered the quantity, duration, and kind of therapy sessions as well as the activities that were conducted. Furthermore, data on every comparison group included in the study was obtained. However, the primary focus of the study was on the outcomes, particularly how the participants' mobility and balance were impacted by the water therapy. Data was also collected regarding the methods used to quantify these outcomes and the conclusions reached. This data was gathered by two reviewers who were completely neutral. The two reviewers would talk over the data if there was anything they couldn't agree on. A third reviewer would be consulted if they were still unable to come to an agreement. This process aims to minimise the possibility that bias or mistakes will influence the outcome.

### *Bias assessment strategy*

To assess the risk of bias within the included studies, the Cochrane's Risk of Bias 2.0 (RoB 2.0) tool [17] was applied. This tool is a comprehensive and validated instrument designed to assess the potential for bias in clinical trials, the results of which has been shown in Figure 2.

### *Statistical analysis*

For the purpose of quantitatively synthesizing the data extracted from the included studies, a meta-analysis was con-

| Database | Search string |
|---|---|
| PubMed | ("Aquatic Therapy"[MeSH] OR "water-based exercise"[Title/Abstract] OR "hydrotherapy"[Title/Abstract]) AND ("Spinal Cord Injuries"[MeSH]) AND ("Balance"[MeSH] OR "Mobility"[MeSH] OR "gait"[Title/Abstract] OR "walking"[Title/Abstract] OR "locomotion"[Title/Abstract]) |
| Web of Science | (TOPIC: ("Aquatic Therapy" OR "water-based exercise" OR "hydrotherapy") AND TOPIC: ("Spinal Cord Injuries") AND TOPIC: ("Balance" OR "Mobility" OR "gait" OR "walking" OR "locomotion")) |
| Scopus | (TITLE-ABS-KEY ("Aquatic Therapy" OR "water-based exercise" OR "hydrotherapy") AND TITLE-ABS-KEY ("Spinal Cord Injuries") AND TITLE-ABS-KEY ("Balance" OR "Mobility" OR "gait" OR "walking" OR "locomotion")) |
| CINAHL | (MH "Aquatic Therapy" OR TI "water-based exercise" OR AB "hydrotherapy") AND (MH "Spinal Cord Injuries") AND (MH "Balance" OR MH "Mobility" OR TI "gait" OR AB "walking" OR AB "locomotion") |
| Cochrane Central Register of Controlled Trials | (ti,ab,kw: ("Aquatic Therapy" OR "water-based exercise" OR "hydrotherapy") AND ti,ab,kw: ("Spinal Cord Injuries") AND ti,ab,kw: ("Balance" OR "Mobility" OR "gait" OR "walking" OR "locomotion")) |
| EMBASE | ('aquatic therapy'/exp OR 'water-based exercise':ab,ti OR 'hydrotherapy':ab,ti) AND ('spinal cord injuries'/exp) AND ('balance'/exp OR 'mobility'/exp OR 'gait':ab,ti OR 'walking':ab,ti OR 'locomotion':ab,ti) |
| PsycINFO | ((DE "Aquatic Therapy" OR "water-based exercise" OR "hydrotherapy") AND (DE "Spinal Cord Injuries") AND (DE "Balance" OR DE "Mobility" OR "gait" OR "walking" OR "locomotion")) |
| PEDro | ((KW "Aquatic Therapy" OR "water-based exercise" OR "hydrotherapy") AND (KW "Spinal Cord Injuries") AND (KW "Balance" OR KW "Mobility" OR "gait" OR "walking" OR "locomotion")) |

Table 1: Search strings utilised across the selected databases

ducted using the Review Manager software (RevMan 5, version 5.4.1) provided by the Cochrane Collaboration. The mean difference (MD) was calculated to compare the efficacy of AT in improving balance (gait) and mobility in individuals with SCI. The random-effects (RE) model was employed for the meta-analysis due to the expected heterogeneity among the included studies. Forest plots were generated to display the MD for each study along with the corresponding 95% confidence interval (CI). Statistical heterogeneity was assessed using the $I^2$ statistic.

## 3. Results

### *PRISMA Protocol*

The identification phase began with a comprehensive search of various databases and registers, which initially yielded 392 records. No additional records were identified through registers. The screening phase commenced with the removal of duplicates, resulting in the exclusion of 68 records. Automation tools were then used to further filter the records, leading to the removal of 31 additional records. No records were removed for other reasons. With the initial exclusions, a total of 293 records remained for screening. In contrast to many studies, none of the records were excluded immediately after the first screening. All 293 records were deemed potentially relevant and were retrieved for further eligibility assessment. In the retrieval phase, 55 reports were not retrievable, leaving 238 reports that were thoroughly assessed for eligibility. Exclusion reasons at this stage included: non-adherence to the Population, Intervention, Comparison, Outcomes (PICO) criteria (86 studies); being animal-based (59 studies); being literature reviews (63 studies); and full-text unavailability (24 studies). After the selection process, six studies [18]–[23] were ultimately included in the review.

### *Population Characteristics Evaluated*

Table 3 presents the demographic variables from the included papers [18]–[23], offering a comprehensive view of the sample characteristics across them. The studies were conducted across three different regions: Italy [18], [22], [23], Brazil [19], [20], and the USA [21]. These studies employed either comparative [18], [20]–[23] or cross-sectional [19] protocols and span a publication period from 1998 [23] to 2022 [18]. The sample sizes in these studies ranged from a minimum of 10 [18] to a maximum of 23 participants [23]. It is noteworthy that the smallest sample size belonged to the most recent study [18], while the largest was found in the oldest research [23]. The age range of participants across the studies was fairly broad, with the youngest age group starting from 18 years [18], [19] and the oldest extending up to 80 years [23]. In terms of gender distribution, a clear predominance of male participants was observed across all studies. The least skewed gender ratio was seen in the study with 15 participants, where just over half were males [22]. In contrast, the most skewed ratio was observed in a study of 19 participants, where all but one were males [19].

| Criteria | Description |
|---|---|
| Inclusion | |
| - Study Design | Included studies were randomized controlled trials, non-randomized controlled trials, and observational studies. |
| - Population | Studies involving adults (18 years and older) with a diagnosis of spinal cord injury were included. |
| - Intervention | Studies that implemented an aquatic therapy program as the primary intervention were included. |
| - Comparison | Studies that compared aquatic therapy to no intervention, conventional therapy, or another form of therapy were included. |
| - Outcomes | Studies that measured outcomes related to balance and mobility (e.g., gait parameters, balance scores, functional mobility tests) were included. |
| - Language | Only studies published in English were included. |
| Exclusion | |
| - Study Design | Case reports, case series, reviews, and letters to the editor were excluded. |
| - Population | Studies involving individuals with conditions other than spinal cord injury were excluded. |
| - Intervention | Studies where aquatic therapy was not the primary intervention or was combined with other interventions such that its effects could not be isolated were excluded. |
| - Outcomes | Studies that did not measure balance or mobility outcomes were excluded. |
| - Full text availability | Studies where the full text was not available were excluded. |

Table 2: Inclusion and exclusion criterion devised for the review

***Parameters Examined***

Table 4 shows the major findings related to AT obtained from the included trials. Fantozzi et al. [18] looked at how AT might affect balance in 10 patients with incomplete SCI. They used wearable sensors to measure changes and focused on the immediate effects of AT. Iucksch et al. [19] compared people with spinal cord injuries to those without any injuries. They had both groups walk in a warm pool and looked at differences in how they moved and controlled their bodies. Silva et al. [20] divided sixteen patients with spinal cord injuries into two groups. One group swam twice a week, and then they measured how this affected their ability to do everyday activities over four months.

Stevens et al. [21] had eleven adults with incomplete-SCI walk on an underwater treadmill three times a week. They looked at how this affected their strength, balance, walking speed, and daily activity over eight weeks. Tamburella et al. [22] compared fifteen people with incomplete SCI and fifteen healthy people. They had them walk on land and in water and looked at differences in how they walked and how their joints moved. Zamparo et al. [23] investigated patients who had different types of muscle stiffness and gave them a two-week hydrotherapy program. They looked at how this affected their energy use and how they walked.

***Balance Analysis (Gait-Related Measurements)***

Fantozzi et al. [18] found that AT increased the duration of the first step and decreased root mean squared accelerations for both the upper and lower trunk. These findings suggest that AT may enhance postural control and stability, particularly during the initiation of gait. Iucksch et al. [19] recorded significant differences in stance phase duration, stride length, and speed during AT, but similar joint angle patterns and no significant differences in the ranges of joint motion between groups. This suggests that AT can influence certain temporal and spatial parameters of gait, but its impact on joint kinematics might be less pronounced. AT was found to induce changes in gait characteristics in SCI patients in the trial by Tamburella et al. [22], including reduction in gait speed and stance phase, increment in gait cycle time, and invariant stride length and range of motion values. This study also noted that AT reduced gait differences between SCI subjects and controls, hinting towards a 'normalizing' effect of AT on gait parameters in SCI individuals. Zamparo et al. [23] reported that hydrotherapeutic intervention successfully

| Study ID | Year | Region assessed | Protocol | Sample size (n) | Age range (in years) | Gender ratio |
|---|---|---|---|---|---|---|
| Fantozzi et al [18] | 2022 | Italy | Comparative | 10 | 18-70 | 9 males |
| Iucksch et al [19] | 2013 | Brazil | Cross-sectional | 19 | 18-57 | 18 males |
| Silva et al [20] | 2005 | Brazil | Comparative | 16 | 21-34 | 14 males |
| Stevens et al [21] | 2015 | USA | Comparative | 11 | >21 | 7 males |
| Tamburella et al [22] | 2013 | Italy | Comparative | 15 | 23-69 | 8 males |
| Zamparo et al [23] | 1998 | Italy | Comparative | 23 | 19-80 | 17 males |

Table 3: Demographics variables observed in the selected studies

improved kinematic gait characteristics, especially at slow speeds, indicating an improvement in balance and stability during gait.

Figure 3 illustrates the MD in gait improvement after using AT, as determined by the RE model. The total effect size across all studies ($MD = -0.33, 95\%CI = -0.45to-0.21$) indicates a statistically significant improvement in gait following AT, as the CI does not cross zero. The heterogeneity statistics ($\tau^2 = 0.00; \chi^2 = 2.90, df = 3, P = 0.41; I^2 = 0\%$) indicate that there is no significant between-study variability. This suggests that the differences observed are likely due to treatment effects rather than variation between the studies. The Z-test for overall effect size was significant ($Z = 5.39, P < 0.00001$), indicating that the overall effect of AT on gait improvement is statistically significant across the studies.

***Mobility (Walking) Analysis***

In Silva et al.'s [20] investigation, the experimental and control groups demonstrated noticeable gains related to body care, transference, and overall and motor scores, with the experimental group exhibiting superior outcomes. These findings suggest AT's potential in facilitating functional improvements, including mobility. Stevens et al. [21] found that patients significantly enhanced their lower extremity strength, balance, walking speeds, 6-minute walking distance, and daily step activity after AT intervention. This highlights the potential of AT to improve various functional mobility components substantially. Zamparo et al. [23] noted reduced subjects' energy expenditure following hydrotherapeutic intervention, potentially translating into improved walking efficiency and mobility over time.

Figure 4 is the forest plot that presents the MD in mobility improvement following AT. The total effect size across all studies ($MD = -0.22, 95\%CI = -0.42to-0.02$) suggests a statistically significant improvement in mobility following AT, as the CI does not cross zero. The heterogeneity measures ($\tau^2 = 0.03; \chi^2 = 14.43, df = 4, P = 0.006; I^2 = 72\%$) show significant between-study variability, indicating that the differences in the results between the studies are not solely due to random chance. The Z-test for overall effect size was significant ($Z = 2.11, P = 0.03$), confirming that the overall effect of AT on mobility improvement across the studies is statistically significant.

Study ID Groups assessed modality employed for AT assessed variables. Follow up period inferences peratining to AT observed variables showcased that in 10 iSCI patients, having four wearable inertial sensors, temporal and acceleration based anticipatory postural adjustment measures were not specified[18].Study by Iucksch et al. showed that Aquatic therapy increased the first step duration and decreased root mean squared accelerations for both the upper trunk and lower trunk [19].

Similarly, SCG and NIG walking at a self selected speed in a heated pool with water at the level of the xiphoid process, temporal-spatial variables and joint range of motion were not specified. It was observed that duration of stance phase, stride length and speed differed significantly between groups.The ranges of joint motion were not significantly different, and the joint angle patterns were qualitatively similar between groups.

Silva et al [20] 16 patients with spinal cord injury divided into experimental and control groups Swimming sessions performed twice a week FIM scale Four months Both groups demonstrated noticeable gains related to body care, transference, overall and motor scores, even though the experimental group presented greater gains in transference, overall motor score and overall score Stevens et al [21] 11 adults with incomplete-SCI Underwater treadmill training, 3 sessions per week Lower-extremity strength, balance, preferred and rapid walking speeds, 6-min walk distance and daily step activity Eight weeks Patients significantly enhanced their lower extremity strength, balance walking speeds, 6 min walking distance and daily step activity Tamburella et al [22] 15 subjects with incomplete SCI and 15 healthy controls Walking in water and on land Kinematic gait parameters and range of motion of joint angles Not specified Gait in water of the SCI patients was characterized by speed and stance phase reduction, gait cycle time increment, and invariance of stride length and range of motion values.

Walking in water reduces gait differences between the groups. Furthermore, in water, the SCI subjects presented a reduction in variability of the hip and knee joint angles, whereas in the controls, a larger variability was observed Zamparo et al [23] spastic paresis patients (12 affected by hemiparesis, 4 by multiple sclerosis and 7 incomplete SCI) Hydrotherapy intervention for 45 min/daily in 32◦C seawater, including passive and active movements, free swimming, and waterimmersion walking Energy expenditure and kinematic gait characteristics 14 days The hydrotherapeutic intervention successfully lowered subjects' energy expenditure and improved kinematic gait characteristics especially at slow speeds Figure 3.

## 4. Discussion

The research papers by Fantozzi et al. [18] and Zamparo et al. [23] focused on how AT can impact how people walk, especially those with specific gait characteristics. Fantozzi et al. [18] found that AT can help people take their first step more quickly and decrease movement in the upper and lower parts of their body. This suggests that AT can help people maintain better posture and stability when walking. Zamparo et al. [23] found that AT can improve how people walk, especially when walking at slow speeds.

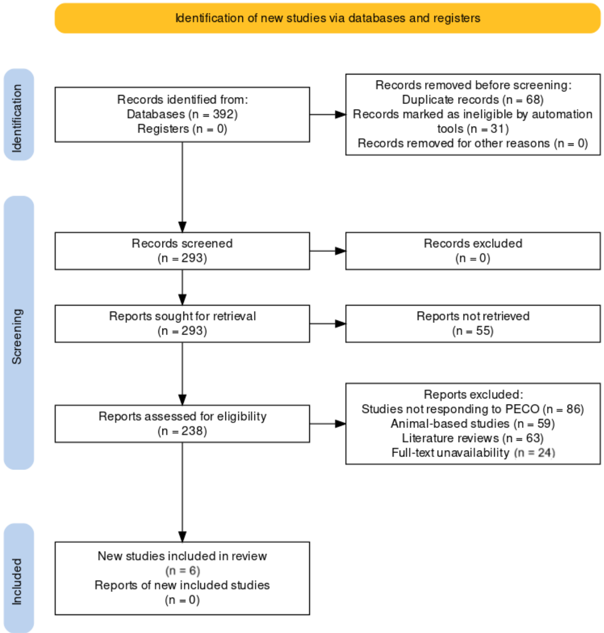


Figure 1: PRISMA protocol representation of the article selection process for the review

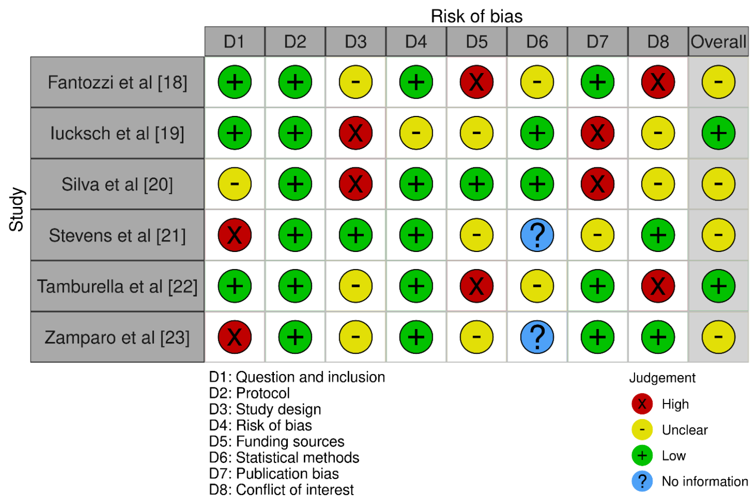


Figure 2: Assessment of bias across different domains in the included papers

| Study ID | Groups assessed | Modality employed for AT | Assessed variables | Follow-up period | Inferences pertaining to AT observed |
|---|---|---|---|---|---|
| Fantozzi et al. [18] | 10 iSCI patients | Four wearable inertial sensors | Temporal and acceleration-based anticipatory postural adjustment measures | Not specified | Aquatic therapy increased the first step duration and decreased root mean squared accelerations for the upper trunk and lower trunk |
| Iucksch et al. [19] | SCG and NIG | Walking at a self-selected speed in a heated pool with water at the level of the xiphoid process | Temporal-spatial variables and joint ranges of motion | Not specified | Duration of stance phase, stride length and speed differed significantly between groups. The ranges of joint motion were not significantly different, and the joint angle patterns were qualitatively similar between groups. |
| Silva et al. [20] | 16 patients with spinal cord injury divided into experimental and control groups | Swimming sessions performed twice a week | FIM scale | Four months | Both groups demonstrated noticeable gains related to body care, transference, overall and motor scores, even though the experimental group presented greater gains in transference, overall motor score and overall score |
| Stevens et al. [21] | 11 adults with incomplete-SCI | Underwater treadmill training, 3 sessions per week | Lower-extremity strength, balance, preferred and rapid walking speeds, 6-min walk distance and daily step activity | Eight weeks | Patients significantly enhanced their lower extremity strength, balance walking speeds, 6 min walking distance and daily step activity |
| Tamburella et al. [22] | 15 subjects with incomplete SCI and 15 healthy controls | Walking in water and on land | Kinematic gait parameters and range of motion of joint angles | Not specified | Gait in water of the SCI patients was characterized by speed and stance phase reduction, gait cycle time increment, and invariance of stride length and range of motion values. Walking in water reduces gait differences between the groups. Furthermore, in water, the SCI subjects presented a reduction in variability of the hip and knee joint angles, whereas in the controls, a larger variability was observed |
| Zamparo et al. [23] | 23 spastic paresis patients (12 affected by hemiparesis, 4 by multiple sclerosis and 7 incomplete SCI) | Hydrotherapy intervention for 45 min/daily in 32°C seawater, including passive and active movements, free swimming, and water-immersion walking | Energy expenditure and kinematic gait characteristics | 14 days | The hydrotherapeutic intervention successfully lowered subjects' energy expenditure and improved kinematic gait characteristics especially at slow speeds |

Table 4: Findings pertaining to AT observed across the included papers

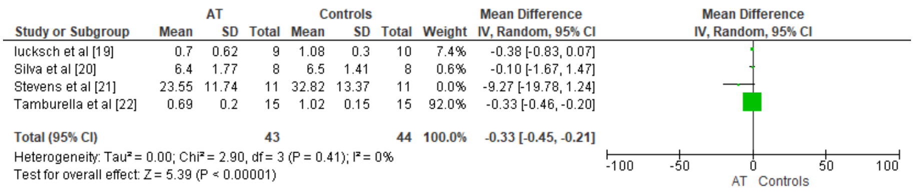


Figure 3: Efficacy of AT in terms of improving gait in the assessed studies

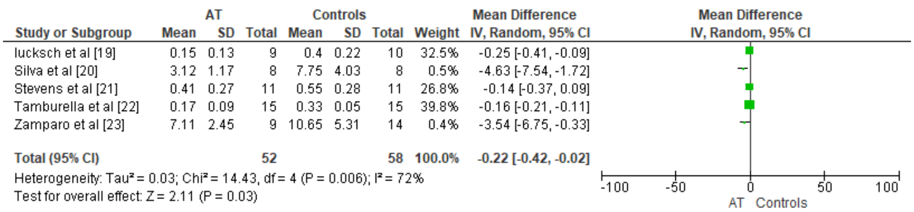


Figure 4: Efficacy of AT in terms of improving mobility in the assessed studies

The research by Tamburella et al. [22], and Iucksch et al. [19] looked at how AT can affect both the timing and spatial aspects of walking. Iucksch et al. [19] found that AT could change how people walk without significantly impacting the movements of their joints. This was seen in the differences in the time people spent standing, their strides, and their speed. However, there were no significant differences in the range of joint motion. Tamburella et al. [22] found that for people with spinal cord injuries, AT made them spend less time in the stance phase, have a longer gait cycle duration, and have slower walking speeds. This suggests that AT might help normalize how people with neurological abnormalities walk.

The research by Silva et al. [20] and Stevens et al. [21] mainly looked at how AT can influence functional mobility. Silva et al. [20] found that both the experimental and control groups improved body care, transferring, and overall motor scores. The experimental group showed even greater improvements, indicating that AT can help improve independence and functional mobility. Stevens et al. [21] found that AT significantly improved lower body strength, balance, walking speeds, the distance covered in 6 minutes of walking, and the number of steps taken each day. Zamparo et al. [23] also found that AT can reduce energy consumption, suggesting that it can help improve walking efficiency, which in turn could improve endurance and mobility.

Our review agrees with the findings of other studies that AT can have therapeutic benefits for people with spinal cord injuries. Other reviews, including ours, have found that AT can improve how people walk, the length of their strides, and their walking speed. One of the studies included in our review, by Zamparo et al. [23], found that AT can reduce energy consumption, which is also a finding of the study by Ellapen et al. [24]. However, Ellapen et al. [24] emphasized the need for more randomized controlled trials (RCTs) to confirm these findings, which was a minor point in our review.

The review by Stanciu et al. [25] went into great depth about how AT can improve respiratory, cardiovascular, and metabolic health and reduce spasticity and discomfort. Our review focused less on these aspects but on how AT can improve walking and mobility. It is worth noting that they also included a broad range of research methods, such as semi-structured interviews, which could provide unique insights into the experiences of people with spinal cord injuries who are receiving AT. Like Ellapen et al. [24], they also highlighted the need for more RCTs. Despite these concerns, they concluded that AT is a crucial part of treating people with spinal cord injuries, which aligns with our overall positive view of AT.

Eleven RCTs were included in Palladino et al.'s [26] analysis; however, only three papers were thoroughly examined because of quality issues. This worry is consistent with the opinions stated in the evaluations of Stanciu et al. [25] and Ellapen et al. [24], which point to the necessity of conducting more high-caliber RCTs. Palladino et al. [26] concentrated on a narrower group of research and used end measures such as the FIM and Ashworth scale, in contrast to our review, which used a wide range of studies and outcome measures. Their conclusions about the benefits of aquatic environments for rehabilitation align with our research on gait stability, functional mobility, and energy efficiency.

The goal of Li et al.'s review [27] was to compile data regarding how water exercise therapies affect people with spinal cord injuries' physical function and fitness. They included eight papers in their analysis, but they needed evidence of excellent research quality, which is consistent with our study and the recommendation made by Palladino et al. [26] for more thorough research. The mobility and energy efficiency improvements seen in our research were reflected in the notable increases in physical function and aerobic fitness reported by Li et al. [27]. Compared to our evaluation, which mainly concentrated on gait characteristics, their suggestion for future research to evaluate other physical or fitness outcomes, such as body composition, muscular strength, and balance, suggests a wider variety of possible advantages of water therapy.

It has been shown that applying AT to SCI patients can improve their cardiorespiratory and thermoregulatory states, improve aquatic limb functionality and walking kinematics, and lessen spasticity. These advantages may lessen issues that result in various degrees of incapacity. The special mechanical, chemical, and physical characteristics of the water used in treatment help hydrotherapy have a therapeutic effect on these issues [28]–[30].

According to specialized literature, spasticity can appear months or even years after an acute SCI, which could result in severe functional impairment and the need for hospitalization [31]. Studies show that signs of spasticity are present in 65-78% of individuals with chronic SCI ($\geq$ 1 year after damage) [32]. Up to five years after a spinal cord injury, about one-third of patients still struggle with issues associated with spasticity [33]. Consequently, any therapeutic measure that improves neurological symptoms is vital to managing the patient's care. Additional clinical trials are necessary to validate the effectiveness of hydrotherapy in this particular situation.

Patients with SCI have increased cardiovascular disease risk factors [34]. This risk is supported by the significant drop in daily energy expenditure observed in patients with SCI due to motor function impairment and reduced possibilities for physical exercise [35]. Furthermore, irregular blood pressure, heart rate variability, arrhythmias, and a reduced cardiovascular response to exercise are associated with SCI, which may limit an individual's capability for physical activity [35]. By boosting cardiorespiratory status, hydrotherapy can be extremely important in improving treatment adherence and the subsequent development of heart symptoms in individuals with spinal cord injuries. As a result, improving cardiovascular health with hydrotherapy is an essential factor to consider when treating SCI patients.

### *Recommendations for Clinical Practice*

Based on the findings from this review and the available literature, AT is somewhat promising as an effective treatment for improving gait and mobility in individuals, especially those with neurological impairments. AT appears to enhance postural control and stability during gait initiation, as indicated by improvements in specific gait parameters such as the duration of the first step and accelerations of the upper and lower trunk. It also influences gait stability positively, particularly at slow speeds. AT's potential extends beyond gait improvement and into modifying gait dynamics. This is reflected in significant changes in stance phase duration, stride length, and speed without impacting joint movements. Furthermore, AT seems to 'normalize' certain gait parameters, such as gait speed, stance phase, and gait cycle time in patients with neurological impairments.

The benefits of AT are not limited to gait parameters and dynamics alone. AT has shown potential in enhancing functional mobility and independence, which are critical for quality of life. This is reflected in notable improvements in body care, transference, overall and motor scores, lower extremity strength, balance, walking speeds, and daily activity levels. AT also improves energy efficiency during gait, indirectly enhancing walking endurance and overall mobility. Despite variations in individual study outcomes, the overall trend indicates a statistically significant improvement in walking ability and mobility for individuals who engage in AT. Therefore, AT is a promising and potentially beneficial approach to improving gait and mobility while maintaining caution and individual considerations when interpreting these results.

### *Limitations of the Review*

The populations studied varied in terms of the severity and type of neurological impairments, age, and other demographic factors, which could impact the effectiveness of AT and the generalizability of the results. Also, some of the studies did not specify the follow-up period, limiting understanding of the long-term effects of AT. With long-term data, concluding the sustainability of AT's benefits over time was easier. Moreover, the measures used to assess outcomes were diverse, ranging from kinematic gait parameters to functional mobility scores. The lack of standardized measures made it challenging to compare results across studies and aggregate data for a more comprehensive analysis.

## 5. Conclusion

The overall findings of the review suggest that individuals may benefit from AT in terms of gait and mobility. When considering all the studies combined, there was a discernible improvement in walking ability and overall mobility in persons who underwent AT compared to those who did not, despite a few individual trials failing to show a significant change. The statistical significance of these advances strongly implies that they were not the result of chance. It is important to remember that while the results were generally encouraging, the research's precise results differed. The populations may explain this variation studied or the distinct procedures applied in each study. As a result, care should be taken when interpreting these findings. However, the data points to AT as a potentially helpful technique for improving gait and mobility.

## Conflict of Interest

The author declares no conflict of interests. Author read and approved final version of the paper.

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