The effects of hydrotherapy on people with cervical spinal cord injury

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ABSTRACT

The primary goal of this study was to systematically review the effects of hydrotherapy in individuals with cervical spinal cord injuries (SCI). The aim was to focus on results in the musculoskeletal, respiratory and cardiovascular systems, the effect on pain and spasticity, as well as the contribution of aquatic therapy to gait retraining and quality of life. Furthermore, it was considered important to identify gaps in the literature and suggest future studies of therapeutic intervention in the aquatic environment in the field of neurological rehabilitation for patients with SCI.

Key words: Hydrotherapy, Spinal cord inury, Cervical spine.

Introduction

Traumatic tetraplegia results in motor, sensory and autonomic deficits that are dependent upon the site and extent of spinal cord damage [13]. Individuals with cervical spinal cord injury (SCI) can present paralysis of the upper and lower limbs and respiratory dysfunction, due to the loss of supraspinal control over the respiratory muscles. Additionally, muscular atrophy and loss of sympathetic activation diminishes venous return and systolic function and as result, it compromises cardiovascular function [6]. The chronic phase of the condition is characterized by loss of motor and sensory function, but also includes symptoms such as autonomic dysreflexia, impairment of bowel and bladder control, pain and spasticity resulting in significant loss of quality of life [34]. Complete spinal cord lesions above the fifth cervical segment, will result in the loss of motor and sensory innervation to some regions of the arms and all regions of the legs, hips and trunk. The loss of the sympathetic division of the autonomic nervous system will also affect cardioacceleration and redistribution of blood flow [14].

The rehabilitation program requires a multidisciplinary approach. The patients can experience severe problems with great impact on their activities of daily living, physical and psychological well being and self-care, mobility, social interaction, accommodation, employment, family support and sexual function. The

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physiotherapists provide a complete assessment of respiratory status, passive range of motion of the joints above and below the level of injury, muscle strength, coordination and function, as well as level of sensation. Each program is then tailored to each patient's needs and the patient is encouraged to work on developing independence with transfers, maximal independence and functional ability [5].

There is evidence to support the use of aquatic therapy (AT) for individuals with spinal cord injury [22]. The wide variety and physical properties of water, like buoyancy, temperature, and hydrostatic pressure make HT a particularly suitable technique for people with SCIs as water facilitates a variety of therapeutic interventions. Buoyancy provides gravity-eliminated support, hydrostatic pressure compresses tissues and promotes lymphatic and venous return, the warm temperature reduces muscle spasm, and viscosity/turbulence provides velocity-dependent and resistance-building strength [29].

The primary goal of this study was to systematically review the effects of hydrotherapy in individuals with cervical spinal cord injuries. The aim was to focus on results in the musculoskeletal, respiratory and cardiovascular systems, the effect on pain and spasticity, as well as the contribution of aquatic therapy to gait retraining and quality of life. Furthermore, it was considered important to identify gaps in the literature and suggest future studies of therapeutic intervention in the aquatic environment in the field of neurological rehabilitation for patients with SCI.

Methods

The research was conducted in English in the following databases: Pubmed, Science Direct, google scholar and PEDro. The following keywords and their combination were used: hydrotherapy, aquatic therapy, rehabilitation, (cervical) spinal cord injury, tetraplegia, quadriplegia, ventilated patient, tracheostomy.

Inclusion and exclusion criteria:

Studies referring to participants with acute or chronic, complete or incomplete SCI, as well as participants with a clinical picture of tetraplegia or tetraparesis were included. Animal studies were excluded.

Studies that used hydrotherapy as an intervention were included. Studies that did not use water exercise as an intervention or part of it were ruled out.

In terms of the type of studies, they can be randomized controlled trials (RCTs), controlled trials, qualitative studies, case studies or case series studies.

Studies referring to the effects of hydrotherapy (improvement of respiratory and cardiovascular function, reducing pain and spasticity, improving function and quality of life) on people with SCIs were included. Due to the small number of studies available, the year the survey was conducted was not of great significance.

The systematic review revealed 902 search-related surveys. After the titles and, where necessary, the abstracts, were screened, 864 surveys were excluded due to non-relevance to the topic. After sorting, 38 articles were evaluated for eligibility, by reading the full text, according to the criteria for inclusion and exclusion of this systematic review. Of these, 21 articles were excluded (7: systematic reviews, 3: animal research, 2 without extensive reference to hydrotherapy, 6: other neurological diseases, 2: children with cerebral palsy). Finally, 18 surveys were included in this review.

The evaluation of the methodological quality of the RCTs in this review was based on the widely used 11-point PEDro scale [19]. The Pedro scale is a valid and reliable tool for evaluating the methodological quality of randomized controlled trials on physiotherapy and rehabilitation [26]. This scale includes eleven quality criteria of methodology. The presence of each criterion in the study is graded with one grade and its absence with zero. The first criterion that describes the origin and the criteria of the sample of a study, is not included in the final score of the study so the lowest and highest score of a study in the Pedro evaluation, ranges from 0 to 10 respectively

Results

Thermoregulation, cardiovascular and respiratory system:

Di Rocco et al. [7], wanted to examine the cardiorespiratory responses of wheelchair users in the aquatic environment. As a result, water has been shown to improve venous return, cardiac output and lung ventilation, and it appeared that nonambulatory

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individuals with low fitness levels were able to experience greater cardiopulmonary work outputs when exercising in the water. In another study, reductions in heart rate and improvement in cardiac output appeared to be the result of 2 months of exercise in the water by individuals with incomplete SCI [32].

Studies of thermoregulatory and cardiorespiratory adaptations after immersion in warm water (39°C) and after exercise in water have shown lower heart rate, higher rectal temperature, lower plasma noradrenaline concentration, and increased plasma volume in a tetraplegic group [16], while in a group of paraplegics (affected sympathetic system, except of one participant), warm water immersion did not produce a significant adaptive response [15].

Regarding to spirometric parameters, it has been shown that immersion at shoulder height improves the VC of people with quadriplegia [19], a fact to which hydrostatic pressure contributes significantly [18]. Finally, significant differences were reported in FVC, FER, FEV1 and FEV1 / FVC [16], while a comparison of 3 months of hydrotherapy and robotic therapy in individuals with chronic incomplete SCIs showed that neither intervention succeeded to statistically improve the maximum VO2 value, although the percentage improvement was greater in the hydrotherapy group [15].

Spasticity, gait retraining and quality of life

In 1999, Pagliaro and Zamparo [28] observed that hydrotherapy contributed to a reduced myotatic reflex response in people with spastic tetraparesis, while in another study where AT was used as an intervention, there was a significant increase in FIM scores, a statistically significant decrease in baclofen oral intake and a significant reduction in spasm severity [17].

Regarding to gait retraining and movement in water, it was shown that the aquatic environment influences the beginning of gait in terms of the center of pressure excursion, impulses, trunk acceleration, and perceptions of participants with incomplete spinal cord injury, improving physical function and the ability to walk [21]. Furthermore, it was proved that the walking pattern of people with SCI in water is related to kinematic parameters similar to those of healthy people, especially in terms of speed, stride length and stance phase [34]. Later, Recio et al [29] observed a significant improvement in the SCIM III score, in the motor part of the AIS scale, and an increase in distance to 6MWT in ambulatory patients.

From the health professionals' point of view, physical, psychosocial and functional benefits were identified through questionnaires. It was reported that in warm water there was a reduction in pain, improvements in well-being, mental health and self-confidence. The aquatic environment gave patients a sense of freedom, something they could not experience on land, but various challenges were also reported, such as lack of (trained) staff and resources, infection control, transportation and participation costs, caregiver support and accessibility [22].

Presence of tracheostomy and invasive appliances

Both Taylor [35] and Wegner et al. [39] in their case studies, applied AT to a patients with tracheostomy and mechanical respiratory support and they noted that through careful planning and proper preparation, hydrotherapy can be successfully and safely integrated into the patient's rehabilitation program. They observed that aquatic therapy can facilitate the patient's ability to actively participate in exercise and rehabilitation and can lead to improved respiratory function, allowing faster weaning from mechanical ventilation and consequently, reducing the length of stay and the cost of intensive care.

Felten-Barentsz et al. [10], after applying a hydrotherapy program to 25 critically ill patients in the intensive care unit with mechanical ventilation, concluded that hydrotherapy seems to be a feasible and safe intervention in critically ill patients, while, later [11], through interviews with critically ill patients with mechanical ventilation, it emerged that hydrotherapy helps patients regain control and faith in their recovery and that exercise in water was an important turning point in their recovery process.

Finally, Recio et al [29] evaluated the interventions used in hydrotherapy and the clinical benefits in people with SCIs who use invasive appliances (bandages for pressure ulcers, indwelling or suprapubic catheters, colostomy bags and tracheostomy tubes) and it was shown that they can safely participate in a specialized hydrotherapy program without complications and

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that they seem to achieve clinically significant benefits.

Discussion

Cardiorespiratory system and thermoregulation

The effect on the cardiovascular system will depend on the extent of the damage to the spinal / central part of the autonomic nervous system. The cardiac changes are caused by loss of supraspinal sympathetic control and relatively increased parasympathetic cardiac control. Decreases in sympathetic activity result in heart rate and the arterial blood pressure changes, and may cause arrhythmias, in particular bradycardia, with the risk of cardiac arrest in those with cervical or high thoracic injuries [4].

Systemic muscular atrophy and loss of sympathetic activation compromises cardiovascular function by diminishing venous return and systolic function. Consequently, cardiopulmonary disease is the most common cause of morbidity following SCI [6].

When a person is immersed in water, the blood shifts to the heart, enhancing venous return, which in turn increases arterial and ventricular filling and leads to a consequent reduction in heart rate [9]. During exercise in the water, the maximum oxygen consumption is higher than that of the exercise on land, allowing greater energy expenditure at lower speeds and prolonged activity. During immersion an individual is subjected to external water pressure in a gradient, which within a relatively small depth exceeds venous pressure, blood is displaced upward through the venous and lymphatic systems [3].

Hydrostatic pressure applied to the thorax and abdomen beneath the surface assists in exhalation improving vital capacity and resists inspiration increasing muscle tension as a signal for growth of muscle mass (hypertrophy). Buoyancy can also act as an abdominal binder, supporting the contents of the abdomen and allowing diaphragm ventilatory parameters to optimize due to supportive pressure beneath the dome of the diaphragm, improving efficiency in contraction and passive exhalation [29].

Below the level of the SCI it is expected that there will be no centrally driven vasomotor or sudomotor activity, resulting in higher skin temperatures and a greater gain in core temperature when the person with a cervical cord lesion is thermally challenged. The reduction in sudomotor and vasomotor function resulting from injury to the spinal cord, combined with a likely reduced total blood volume may lead to higher heat storage for a given thermal stimulus, thereby raising the risk of a heat related disorder. Indeed, passive heat has been reported to be responsible for approximately 3% of all deaths in people with spinal cord injury [13].

Spasticity and pain

Spasticity is a major health problem for patients with SCI, which limits patients' mobility and affects their independence in activities of daily living and work. It may also cause pain, loss of range of motion, contractures, sleep disorders, and impair ambulation in SCI patients. Spasticity creates great difficulty for both the patient and the rehabilitation team. Current therapies for spasticity are far from ideal, and new therapeutic interventions are being explored. Physiotherapy, however, is an important component in the management of spasticity [17], but still, there is not enough research to prove it [2]. As for hydrotherapy, it not only promotes functional recovery, but it can also improve spasticity as part of the treatment program [29].

In a study of children with cerebral palsy, aquatic therapy was shown to be effective in reducing spasticity [1], while a study in patients after a stroke showed that hydrotherapy could increase muscle strength of the affected limb without increasing spasticity [40]. Finally, in a study of patients with peripheral neuropathies, it was found that only 'in-water' patients experienced a reduction in neuropathic pain [41].

Kesiktas et al [17] noted that the side effects of oral medication for the management of spasticity are known and that adding hydrotherapy to the rehabilitation program may be helpful in reducing the amount of medication required.

Muscular system and joints

Frye et al [12] in their study of people with cervical SCI observed that participants had limitations in forearm pronation and elbow extension and increased shoulder and wrist extension. One third of the participants presented elbow overextension and ankle

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plantar flexion contractures were found in many participants.

As the body is gradually immersed, buoyancy provokes offloading of immersed joints. With immersion to the neck, only the approximate weight of the head (15lb) is exerted on the spine, hips, and knees. With immersion to the symphysis pubis, a person has effectively offloaded 40% of his body weight, and approximately 50% when immersed to the umbilicus. Xiphoid immersion offloads body weight by 60% or more [3]. Buoyancy allows to individuals with SCI to become mobile in the water without the resistance of gravity and they can safely, spontaneously and independently exercise. The water stabilizes their lumbopelvic hip, thoracic and cervical muscles and they can exercise without relying on the use of their upper limbs in order to support their posture, as happens during land-based exercises. This can be a key in the prevention of upper limb overuse injuries [9].

Common techniques performed in hydrotherapy for patients with spinal cord injury include stretching, muscle strengthening, balance improvement and gait retraining. These techniques prepare the achievement of functional mobility using exercise focused on daily activities and are integrated into a patient-centered exercise program [29].

Early intervention

Early mobilization can improve outcomes in critically ill patients with or without mechanical ventilation support. Although the data available suggest that mobilization in a therapeutic pool is able to enhance recovery in very weak patients, there are potential challenges and safety issues when it is applied to mechanically ventilated patients [20]. The risks of taking anyone into a pool are already described in the Chartered Society of Physiotherapy's 2006 Guidance on Good Practice in Hydrotherapy, but as it is a relatively novel rehabilitation strategy, its wide use across international facilities seems to be low [39]. Criteria for excluding such patients from hydrotherapy program may include high ventilator support, vasopressors, severe agitation, large wounds, and colonization with multiresistant bacteria [10].

Airway management is critical when undertaking hydrotherapy with ventilated patients and planning must consider airway security and safety. Ventilator disconnection or aspiration of pool water through incorrect positioning or support by staff are the main risks to the airway. When in the water, one therapist should support the head and shoulders of the patient and have direct visualization of the ETT/tracheostomy site to ensure it is maintained above the water [39].

Maling et al. [20], reviewed eleven studies that mainly focused on laryngectomy patients and although they were mostly case studies that contained limited data, they provided information that was useful in creating a Risk Management Tool.

Chronic phase and quality of life

The increasing rates of injury hospitalizations, improved trauma systems and acute care units are giving rise to higher numbers of trauma survivors [8]. Severe neurological deficits limit functional independence, participation and perception of general health, and consequently decrease the physical activity [30]. Long-term lack of physical activity and excessive sedentary behavior are related to, cancer, heart disease, type 2 diabetes and all-cause mortality. This information may be used to help people resume and manage physical activity after trauma and potentially reduce avoidable health decline in the years thereafter [8].

The aim of rehabilitation in patients after SCI is to provide them with as much autonomy as possible. It is of high importance to focus on the ability to perform activities of daily living such as dressing, personal hygiene, eating, computer operation, or mobility in indoor and outdoor environments [31]. It is noted that there is a need for improvement in early counselling between the medical/surgical and rehabilitation teams, along with the patients and family, in order to set realistic goals early during the first days after the injury [30].

In the study by Ekegren et al. [8], it was shown that 3 to 5 years after the injury, participants perceived a high level of physical inactivity due to fear of re-injury, pain and lack of proper clinical guidance. These restrictions were a source of distress, given the perceived impacts on health, social lives and family roles. Participants who were participating in regular physical activity

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recognized the value of social supports, sources of funding and their own self-motivation in promoting participation.

Difficulties and obstacles

Unfortunately, hydrotherapy is not always available to all patients with SCI due to various comorbidities, neurogenic bowel-bladder, colostomies with attached collection bags etc that could potentially create barriers to their participation [29]. However, the reduced use of AT in people with SCI may not only be due to the presence of comorbidities. For example, lack of trained professionals, limited time for AT in rehabilitation centers, and lack of knowledge of its benefits can be potential barriers. Some of them could be mitigated by educating health professionals, patients and community stakeholders about the benefits of providing AT [22].

Restrictions

Some of the main limitations of this study were the number of databases used, as well as the limitation of the English language. The limited number of surveys available, as well as their low methodological quality, are also significant limitations of this review.

Results - Suggestions

The main finding of this study is that the use of hydrotherapy has been shown to cope with the rehabilitation requirements of people with SCI, from a very early stage, with the presence of tracheostomy and other invasive devices, in the hypoxic and chronic stages. Nevertheless, there is a great need for more research of higher quality and validity, in order to develop specialized protocols and safety measures, for not only the greater participation of these patients in the hydrotherapy program, but also for more appropriate information of the health professionals.

REFERENCES

1. Adar, S., U. Dundar, U. S. Demirdal, A. M. Ulasli, H. Toktas and O. Solak. The effect of aquatic exercise on spasticity, quality of life, and motor function in cerebral palsy. *Turk J Phys Med Rehabil* 2017; 63(3) 239-248.
2. Barbosa P.H.F.d.A., Glinsky J.V., Fachin-Martins E., Harvey L.A. Physiotherapy interventions for the treatment of spasticity in people with spinal cord injury: a systematic review. *Spinal Cord* 2021; 59, 236–247.
3. Becker, B. E. Aquatic therapy: scientific foundations and clinical rehabilitation applications. *PM R* 2009; 1(9) 859-872.
4. Biering-Sorensen, F., M. J. DeVivo, S. Charlifue, Y. Chen, P. W. New, V. Noonan, M. W. M. Post and L. Vogel. International Spinal Cord Injury Core Data Set (version 2.0)-including standardization of reporting. *Spinal Cord* 2017; 55(8) 759-764.
5. Darwish S., Tsirikos A., Maguire S. Rehabilitation following spinal cord injury. *Spinal Injuries* 2020; 34(5) 315-319
6. Dawkins, T. G. and B. A. Curry. Respiratory muscle training in spinal cord injury: a breath of fresh air for the heart. *J Physiol* 2019; 97(23) 5533-5534.
7. DiRocco, P., A. Hashimoto, I. Daskalovic and E. Langbein. Cardiopulmonary responses during arm work on land and in a water environment of nonambulatory, spinal cord impaired individuals. *Paraplegia* 1985; 23(2) 90-99.
8. Ekegren, C. L., S. Braaf, S. Ameratunga, J. Ponsford, A. Nunn, P. Cameron, R. A. Lyons and B. J. Gabbe. Adaptation, self-motivation and support services are key to physical activity participation three to five years after major trauma: a qualitative study. *J Physiother* 2020; 66(3) 188-195.
9. Ellapen, T. J., H. V. Hammill, M. Swanepoel and G. L. Strydom. The benefits of hydrotherapy to patients with spinal cord injuries. *Afr J Disabil* 2018; 7(0) 450.
10. Felten-Barentsz, K. M., A. J. Haans, A. S. Slutsky, L. M. Heunks and J. G. van der Hoeven. Feasibility and safety of hydrotherapy in critically ill ventilated patients. *Am J Respir Crit Care Med* 2015; 191(4) 476-477.
11. Felten-Barentsz, K. M., R. van Oorsouw, A. J. C. Haans, J. B. Staal, J. G. van der Hoeven and M. G. W. Nijhuis-van der Sanden. Patient views regarding the impact

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of hydrotherapy on critically ill ventilated patients: A qualitative exploration study. *J Crit Care* 2018; 48 321-327.
12. Frye, S. K., P. R. Geigle, H. S. York and W. M. Sweatman. Functional passive range of motion of individuals with chronic cervical spinal cord injury. *J Spinal Cord Med* 2020; 43(2) 257-263.
13. Gass, E. M. and G. C. Gass. Thermoregulatory responses to repeated warm water immersion in subjects who are paraplegic. *Spinal Cord* 2001; 39(3), 149-155.
14. Gass, E. M., G. C. Gass and K. Pitetti. Thermoregulatory responses to exercise and warm water immersion in physically trained men with tetraplegia. *Spinal Cord* 2002; 40(9) 474-480.
15. Gorman, P. H., Scott, W., VanHiel, L., Tansey, K. E., Sweatman, W. M., & Geigle, P. R. Comparison of peak oxygen consumption response to aquatic and robotic therapy in individuals with chronic motor incomplete spinal cord injury: a randomized controlled trial. *Spinal Cord* 2019; 57(6), 471-481.
16. Jung, J., E. Chung, K. Kim, B. H. Lee and J. Lee. The effects of aquatic exercise on pulmonary function in patients with spinal cord injury. *J Phys Ther Sci* 2014; 26(5) 707-709.
17. Kesiktas, N., N. Paker, N. Erdogan, G. Gulsen, D. Bicki and H. Yilmaz. The use of hydrotherapy for the management of spasticity. *Neurorehabil Neural Repair* 2004; 18(4) 268-273.
18. Leal, J. C., S. R. Mateus, T. A. Horan and P. S. Beraldo. Effect of graded water immersion on vital capacity and plasma volume in patients with cervical spinal cord injury. *Spinal Cord* 2010; 48(5) 375-379.
19. Maher C. G., Sherrington C., Herbert D., Moseley A., Elkins M. Reliability of the PEDro Scale for Rating Quality of Randomized Controlled Trials. *Physical Therapy* 2003; 83(8) 713–721.
20. Maling H., Grady S. Aquatic therapy for clients with a tracheostomy. *CSP SKIPP* 2012; Evidence Note 02
21. Marinho-Buzelli, A. R., A. M. F. Barela, B. C. Craven, K. Masani, H. Rouhani, M. R. Popovic and M. C. Verrier. Effects of water immersion on gait initiation: part II of a case series after incomplete spinal cord injury. *Spinal Cord Ser Cases* 2019; 5 84.
22. Marinho-Buzelli A. R., C. Gauthier, K. Chan, A. M. Bonnyman, A. Mansfield and K. E. Musselman. The state of aquatic therapy use for clients with spinal cord injury or disorder: Knowledge and current practice. *J Spinal Cord Med* 2022; 45(1) 82-90.
23. Marinho-Buzelli, A. R., H. Rouhani, B. C. Craven, K. Masani, J. A. Barela, M. R. Popovic and M. C. Verrier. Effects of water immersion on quasi-static standing exploring center of pressure sway and trunk acceleration: a case series after incomplete spinal cord injury. *Spinal Cord Ser Cases* 2019; 5: 5.
24. Marinho-Buzelli, A. R., K. Masani, H. Rouhani, A. M. Barela, G. T. B. Fernandes, M. C. Verrier and M. R. Popovic. The influence of the aquatic environment on the center of pressure, impulses and upper and lower trunk accelerations during gait initiation. *Gait Posture* 2017; 58 469-475.
25. Marinho-Buzelli A. R., A. J. Zaluski, A. Mansfield, A. M. Bonnyman and K. E. Musselman. The use of aquatic therapy among rehabilitation professionals for individuals with spinal cord injury or disorder. *J Spinal Cord Med* 2019; 42(sup1) 158-165.
26. de Morton N. A. The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. *The Australian journal of physiotherapy* 2009; 55(2), 129–133.
27. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021; 372:n71
28. Pagliaro, P. and P. Zamparo. Quantitative evaluation of the stretch reflex before and after hydro kinesy therapy in patients affected by spastic paresis. *J Electromyogr Kinesiol* 1999; 9(2) 141-148.
29. Recio, A. C., E. Kubrova and S. A. Stiens. Exercise in the Aquatic Environment for Patients With Chronic Spinal Cord Injury and Invasive Appliances: Successful Integration and Therapeutic Interventions. *Am J Phys Med Rehabil* 2020; 99(2) 109-115.
30. Richard-Denis, A., C. Thompson and J. M. Mac-Thiong. Quality of life in the subacute period following a cervical traumatic spinal cord injury based on the initial severity of the injury: a prospective cohort study. *Spinal Cord* 2018; 56(11) 1042-1050.

31. Rupp, R. Spinal cord lesions. *Handb Clin Neurol* 2020; 168 51-65.
32. Stevens, S. L., J. L. Caputo, D. K. Fuller and D. W. Morgan. Effects of underwater treadmill training on leg strength, balance, and walking performance in adults with incomplete spinal cord injury. *J Spinal Cord Med* 2015; 38(1) 91-101
33. Stevens, S. L. and D. W. Morgan. Heart rate response during underwater treadmill training in adults with incomplete spinal cord injury. *Top Spinal Cord Inj Rehabil* 2015; 21(1) 40-48.
34. Tamburella, F., G. Scivoletto, E. Cosentino and M. Molinari. Walking in water and on land after an incomplete spinal cord injury. *Am J Phys Med Rehabil* 2013; 92(10 Suppl 2) e4-15.
35. Taylor, S. The ventilated patient undergoing hydrotherapy: a case study. *Aust Crit Care* 2003; 16(3) 111-115.
36. Thygesen, M. M., A. B. Jonsson, M. M. Rasmussen, T. H. Nielsen and H. Ksch. Characteristics in a traumatic spinal cord injury population. *Dan Med J* 2020; 67(4).
37. Thomaz, S., P. Beraldo, S. Mateus, T. Horan and J. C. Leal. Effects of partial isothermic immersion on the spirometry parameters of tetraplegic patients. *Chest* 2005; 128(1) 184-189.
38. Wall, T., L. Falvo and A. Kesten. Activity-specific aquatic therapy targeting gait for a patient with incomplete spinal cord injury. *Physiother Theory Pract* 2017; 33(4) 331-344.
39. Wegner, S., P. Thomas and C. James. Hydrotherapy for the long-term ventilated patient: A case study and implications for practice. *Aust Crit Care* 2017; 30(6) 328-331.
40. Zhang, Y., Y. Z. Wang, L. P. Huang, B. Bai, S. Zhou, M. M. Yin, H. Zhao, X. N. Zhou and H. T. Wang. Aquatic Therapy Improves Outcomes for Subacute Stroke Patients by Enhancing Muscular Strength of Paretic Lower Limbs Without Increasing Spasticity: A Randomized Controlled Trial. *Am J Phys Med Rehabil* 2016; 95(11) 840-849.
41. Zivi, I., S. Maffia, V. Ferrari, A. Zarucchi, K. Molatore, R. Maestri and G. Frazzitta. Effectiveness of aquatic versus land physiotherapy in the treatment of peripheral neuropathies: a randomized controlled trial. *Clin Rehabil* 2018; 32(5) 663-670.

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