Advs Exp. Medicine, Biology - Neuroscience and Respiration
DOI 10.1007/5584_2018_164

Rehabilitation of Neuromotor Disabilities in Aquatic Microgravity Environment

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Abstract

The aquatic environment has a high potential in rehabilitation treatment of acute lesions and in chronic diseases. The Safe Bearing Back method is proposed to stimulate the reorganization of deteriorated sensory neuromotor skills. The aim of the present study was to verify the effectiveness and the long-term maintenance of the benefits of a specific thermal rehabilitation training in neuromotor and neurological disabilities. Seventy four patients were evaluated using the Functional Independence Measure (FIM), Tinetti Gait-Balance Scale (TIN), and Visual Analog Scale (VAS) for pain. In addition, a general health index was developed, conceived as a linear combination, with unit weights, of the normalized FIM, TIN, and VAS indicators. Measurements were made at T1 (baseline before treatment), T2 (after a five-month treatment, which was the end of treatment), and T3 (6 months after the end of treatment). Self-sufficiency, walking ability, and subjective pain perception were improved after the treatment. The improvement tapered off during the six-month-long follow-up, but the patients' condition remained well compared with the baseline level before the implementation of the treatment program. We conclude that hydrokinesitherapy with the Safe Bearing Back method demonstrates is clearly effective in the immediate and medium-term rehabilitation of neuromotor diseases.

Keywords

Aquatic microgravity environment · Chronic disease · Health index · Hydrokinesitherapy · Neuromotor disabilities · Rehabilitation · Treatment program

1 Introduction

Many studies have shown that the aquatic environment has a high potential for rehabilitation in the treatment of acute lesions and in chronic diseases, but nowadays its use is rather modest. Several studies have supported rehabilitation therapy in the aquatic microgravity environment to improve static and dynamic balance in a variety

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of pathological conditions (Marinho-Buzelli et al. 2017; Carere and Orr 2016; Barker et al. 2014; Hall et al. 2008). Water immersion can be considered a form of sensory and mechanical agitation applied to patients. The analgesic effect of water is due to heat and buoyancy that are able to block nociception by acting on mechanical and heat receptors, and thus also on the mechanisms of spinal segmental transmission (Lange et al. 2006; Bender et al. 2005). During immersion in hot water, body's temperature rises, causing a reduction in gamma fiber activity; consequently reducing muscle activity and spasticity. These effects increase a range of motion and improve the muscle-joint alignment, which is conducive to rehabilitation efficacy (Furnari et al. 2014; Bellomo et al. 2012).

In rehabilitation of neurological pathologies of both adult and pediatric age, the focus is on four main objectives: proprioceptive training, recruitment of synergic muscles, reduction of hyperreflexia, and spasticity, and muscle strengthening (Lambeck 2001; Gehlson et al. 1984). The benefits of hydrokinesitherapy have to do with a reduction in the level of load, which provides it a better working environment in case of postural instability or anomalous load distribution (Kesiktas et al. 2004). Spasticity is one of the main causes of disability and is usually a challenge in the management of various neurological disorders. During the development of spasticity, the spinal cord undergoes changes in motor neuron excitability, interneuronal connections, and reflexes (Stein 2004). That also involves a modification in muscle tone, which likely results from alterations in the ascending reticulo-spinal pathways and spinal cord interneuronal circuits, along with dysfunction of the corticospinal system. Consequently, segmental imbalance, alterations in inhibitory control, and neuronal sprouting are observed (Ballaz et al. 2011). Pharmacologically, spasticity is often cured with baclofen, a central agonist of $GABA_B$ receptors, belonging to the class of amino-butyric acid derivatives. Baclofen is the most commonly used drug and is usually administered orally or intrathecally as a liquid preparation administration (Rekand 2010). The predominant effect of $GABA_B$ receptor modulation is a reduction of calcium cellular inflow that inhibits the release of excitatory neurotransmitters, including glutamate and aspartate. Baclofen relaxes the muscles and, consequently, improves painful spasms and clones (Faraj 2017). The most commonly reported side effects in clinical trials, particularly in the elderly or patients with cognitive impairment are sedation, drowsiness, weakness, paresthesia, and nausea and vomiting (Brennan and Whittle 2008).

Thanks to therapies in a water microgravity environment, it is possible to reduce the intake of drugs, without being confronted with their side effects. The goal of some neurological rehabilitation techniques is to provide additional sensory information to the patient about bodily oscillations and spatial orientation (Yalcinkaya et al. 2014). Water immersion is considered the only sensory perturbation applied to those who stand in the water (Pöyhönen and Avela 2002). Visual sensory deprivation, while remaining in the aquatic environment, could potentially lead to further instability as shown in previous studies in a different scenario of sensory perturbation (Kjellgren and Westman 2014). Considering the immersion mechanisms in maintaining the postural stability, aquatic rehabilitation programs can be developed in a targeted manner (Louder et al. 2014). Microgravity, combined with specific peripheral receptor stimuli, plays a fundamental role in the technique used (Marinho-Buzelli et al. 2017). The maintenance of a standing position in neurological pathologies is a complex task that is achieved through the integration of sensory information from the visual, vestibular, and somatosensory systems (Bellomo et al. 2012). A way to manage neuromotor disability is to supplement or replace the limited, altered, or missing sensory information by providing additional information to the central nervous system *via* alternative stimulation, which aims at restoring balance (Jung et al. 2017). The aquatic microgravity environment provides is one way to provide such an alternative mechanical input for proprioceptive training to maintain posture. This kind of environment is indicated for treatment of Parkinson's disease, particularly in the initial stage where there is not yet major stiffness and the walking ability is still preserved (Ayán and Cancela 2012).

Buoyancy is one of the physical properties of water that provides postural support and reduces the load on the joints, which enables the patients with cerebral palsy to resume independent moving (Kesiktas et al. 2004). Buoyancy is a force that helps sustain body motion in the water, which underlines the efficacy of hydrotherapy in patients with different physical disabilities such as amputation, cerebral palsy, and paraplegia (Ballaz et al. 2011; Kelly and Darrah 2005). Hydrotherapy also improves respiratory and cardio-respiratory functions, self-esteem, and self-awareness (Prins 2009; Sheldahl et al. 1987). The literature shows that rehabilitation in a water microgravity environment is useful not only in postural rehabilitation, but also in neuromotor and neurocognitive treatment (Schaefer et al. 2016; Šrámek et al. 2000).

The goal of this experimental study was to demonstrate the immediate effects and their medium-term upholding of a sequential therapeutic approach that includes motor and manual therapy in the aquatic environment. To pursue this goal, we introduced an innovative general health index (GHI), which consists of a linear combination of the most common measures of the assessment of autonomy, balance, gait, and pain.

2 Methods

2.1 Study Design

The study was conducted in accordance with the Declaration of Helsinki for Human Research and a local Ethics Committee's indications. This clinical trial was conducted in the Department of Physical Medicine and Rehabilitation of the "G. d'Annunzio" University of Chieti-Pescara in collaboration with 'Fonte Della Salute La Cavallina' Thermal Rehabilitation Center of Castelnuovo della Daunia (FG) in Italy. The study sample consisted of 74 patients with neuromotor disabilities who were divided into four subgroups with the following pathological features:

- Group I: 18 patients with infant cerebral palsy (PCI), with mild mental retardation and limb spasticity;
- Group II: 18 chronic stroke patients, with spasticity but no mental retardation;
- Group III: 10 patients with peripheral nerve injury and 8 with inflammatory degenerative joint processes, with no spasticity or mental retardation, predominantly with orthopedic and rheumatic problems;
- Group IV: 20 patients with Down syndrome, with strong mental retardation.

The following inclusion criteria were applied:

- Neuromotor disability certified by the National Healthcare System of $\geq$67%; the Italian lower cut-off to attest the presence of disability;
- Score of Mini-Mental State Examination (MMSE) $\geq$18; a time-proven and internationally recognized test for the assessment of intellectual and cognitive deterioration. A total score is between 0 and 30 points. A score <18 indicates a serious cognitive impairment, $\geq$18 and $\leq$25 a moderate impairment, and $\geq$26 and 30 a cognitive normality (Folstein et al. 1975).

Exclusion criteria were as follows: severe cardiopathies, infections and mycosis, hypersensitivity to chlorine, fever, open wounds, urinary incontinence, and serious cognitive disability.

2.2 Study Procedures and Outcome Measures

Measurements and questionnaire evaluation was performed at the following sampling times of the study protocol: T1 (baseline before treatment), T2 (after a five-month treatment, which was the end of treatment), and T3 (6 months after the end of treatment) outlined above. The following questionnaires were used as the outcome measures:

1. Functional Independence Measure (FIM) to assess the daily-life activities related to personal care, sphincter control, commuting mobility, locomotion, interpersonal

communication, cognitive and memory skills; ≤18 points = disability; 126 = self-sufficiency.
2. Tinetti (TIN) scale, also known as the Performance-Oriented Mobility Assessment (POMA) to assess the balance stability and cognition in healthy or moderate dementia patients. The scale is concerned with the position changes, balance maneuvers, and the movement aspects for safe and efficient running of daily-life activities; the scale consists of two sections: one for balance and one for gait; 0 = patient cannot walk alone; 28 = patient proficient in walking.
3. Visual Analog Scale (VAS) for the evaluation of painful perception, with 0 = absence of pain; 10 = maximum pain.

Moreover, D-VAS-2 and D-VAS-3, D-FIM-2 and D-FIM-3, and D-TIN-2 and D-TIN-3 indicate the differences between T2-T1 and T3-T2 time points of measurements.

2.3 Intervention Protocol

All patients were treated with the Safe Bearing Back method. This method is an integrated rehabilitation technique consisting of a peripheral sensorineural stimulation performed in an aquatic microgravity environment, using sequential motor education and myofascial manual therapy. The patients underwent five treatment cycles consisting of 20 daily sessions, lasting for 30 min each. The 30-min treatment consisted of the following stages:

- ≈ 5 min of adaptation to the aquatic environment and relaxation;
- ≈ 5 min dedicated to walking;
- ≈ 10 min dedicated to neuromuscular manual therapy, focusing attention on primary trigger points;
- ≈ 10 min dedicated to proper joint mobility, proprioceptive increase and muscle strengthening.

In this study, drawing on the literature (Baena-Beato et al. 2014) and also on our own experience, we used a protocol consisting of five weekly aquatic rehabilitation sessions, with the alternating phases of static and dynamic work phases and the adaptation of external workloads, according to the individual characteristics of each patient. Therapy in a microgravitary aquatic-thermal environment is a great alternative for all those patients who have a high risk of falling and report joint pain that limit the patient in walking (Arnold et al. 2008). The analgesic effects of hydrotherapy have also been studied in patients with arthralgia developing in the course of hormonal therapy; with an overall decrease in pain perception being documented (Baena-Beato et al. 2014; Cantarero-Villanueva et al. 2013). In addition, the efficacy of hydrotherapy is also reported concerning the balance, posture, and walking ability in elderly patients (Ayán and Cancela 2012; Momberg et al. 2008; Rissel 1987) and in patients with orthopedic pathologies. There is also improvement in pain relief in prosthetic patients and in patients with neurological problems (Valtonen et al. 2010; Zamarioli et al. 2008). The Safe Bearing Back rehabilitation method used in the present study is an algo-osteo-myofascial approach that involves specific receptor-mediated motor and tissue stimulation, activation of neural reflexes, and the use of biomechanical load principles for soft tissue, all in the aquatic microgravity environment (Bellomo et al. 2012; Saggini et al. 2008).

3 Statistical Evaluation

Data were collected at the T1, T2, and T3 time points to determine how the patients, treated during the hydrotherapy period, recovered and maintained the cognitive and motor skills afterwards. Differences in the mean values of FIM, TIN, and VAS scores at these time points, for each questionnaire, were evaluated with one-way ANOVA for repeated measurements, followed by Tukey's *post hoc* test. Normality of data distribution was tested with the Jarque-Bera test while the covariance sphericity with the

Mauchly test. The FIM and TIN data violated the normality and sphericity assumptions, so that these data were subjected to the following transformation to meet the normality and sphericity assumptions:

$$\mathrm{FIM}_{\mathrm{trasf}} = \mathrm{Log}\left[\left(\max_{(\mathbf{FIM})} + 1\right) - (\mathrm{FIM})\right]$$
$$\mathrm{TIN}_{\mathrm{trasf}} = \mathrm{Log}\left[\left(\max_{(\mathbf{TIN})} + 1\right) - (\mathrm{TIN})\right]$$

To jointly consider the aspects of FIM, TIN and VAS variables, a general health index (GHI) was introduced. This index is designed as a linear combination, with unitary weights, as follows:

$$\mathrm{GHI} = \alpha \bullet \mathrm{FIM} + \beta \bullet \mathrm{TIN} + \gamma \bullet \mathrm{VAS}$$

where $0 \leq \mathrm{GHI} \leq 3$, and $0 \leq \alpha, \beta, \gamma \leq 1$ (in this case, we consider $\alpha, \beta, \gamma = 1$). FIM, TIN, and VAS scores were normalized, yielding.

$$0 \leq \mathrm{FIM}, \mathrm{TIN}, \mathrm{VAS} \leq 1$$

For the GHI, VAS score was inverted to ensure its accordance with the FIM and TIN variables (i.e., higher VAS values after the inversion should be interpreted as an improvement in the subjective perception of pain; the VAS values now being in line with FIM and TIN values that directly corresponded to patients' improvement). Of note, VAS values were not present for patients belonging to Group IV, because they were unable to give a reliable answer to the subjective perception of pain due to severe mental retardation. Hence, GHI was calculated for a 54 unit sample. The GHI is a measure that varies between a minimum of 0 and maximum of 3 because it consists of three sub-indicators, each ranging from 0 to 1. Thus, GHI equalled zero when a patient had serious shortcomings in self-sufficiency and walking, and had a strong perception of pain. The index equalled three the patient was not suffering from severe pain and has a high degree of independence and the ability to walk. Differences in GHI were evaluated with one-way ANOVA and the *post hoc* test as above outlined. A p-value <0.05 defined statistically significant differences. The tests were performed with the R statistical software.

4 Results

Table 1 shows the descriptive analysis of variables at T1, T2 and T3 time points of measurements. The minimum patient age is 12 years and the maximum is 83 years. The sample is composed by 47% of males and of the mean age of is 50.4 years ±19.3. The mean of FIM score was 87.9 at T1, with a minimum of 18 and a maximum of 124 points. The mean TIN score was 14.3 ± 7.1 at T1, with a minimum of 0 and a maximum of 25 points. The mean VAS score was 8.3 ± 1.4 at T1, with a minimum of 5 and maximum of 10 points. This last score was calculated in a smaller sample of 54 patients, since Group IV patients were excluded due to severe cognitive disability, making it impossible to obtain subjective responses.

Table 2 contains the correlation coefficients between each variable and the others for combinations of ten variables. The variables correspond to patient age and the three questionnaires' data, each obtained at the three time points of measurements. The arrangement of

Table 1 Questionnaire scores – continuous data

Observation	n	Mean ± SD	Median (Min–Max)
Age (year)	74	50.4 ± 19.3	54 (12–83)
FIM-1	74	87.9 ± 28.3	96.5 (18–124)
FIM-2	74	100.1 ± 27.7	110 (21–126)
FIM-3	74	93.45 ± 28.8	104 (19–126)
TIN-1	74	14.3 ± 7.1	16 (0–25)
TIN-2	74	17.8 ± 8.1	20 (0–28)
TIN-3	74	16.4 ± 7.8	18.5 (0–28)
VAS-1	54	8.3 ± 1.4	8.5 (5–10)
VAS-2	54	4.7 ± 1.6	5 (1–9)
VAS-3	54	6.5 ± 1.7	7 (2–10)
D-FIM-2		12.2 ± 12.1	8.5 (2–84)
D-FIM-3		−6.7 ± 10.9	−4 (−80–0)
D-TIN-2		3.5 ± 2.5	3 (0–11)
D-TIN-2		−1.4 ± 2.4	−1 (−10–10)
D-VAS-2		−2.7 ± 1.9	−3 (−6–0)
D-VAS-3		1.4 ± 1.3	1 (−1–25)

FIM-1, FIM-2, and FIM-3; TIN-1, TIN-2, and TIN-3; VAS-1, VAS-3, and VAS-3 are Functional Independence Measure scale, Tinetti scale, and Visual Analog Scale, respectively, at T1, T2, and T3 time measurement points. D-FIM-2 and D-FIM-3, D-TIN-2 and D-TIN-3, D-VAS-2 and D-VAS-3 indicate the differences between T2-T1 and T3-T2 time points of measurements

Table 2 Correlation matrices of variables – Bravais-Pearson's index with a list-wise deletion

	AGE	FIM-1	FIM-2	FIM-3	TIN-1	TIN-2	TIN-3	VAS-1	VAS-2	VAS-3
AGE		0.452*	0.468*	0.487*	0.437*	0.459*	0.442*	0.067	−0.009	0.098
FIM-1			0.964*	0.977*	0.799*	0.827*	0.812*	−0.002	0.112	0.067
FIM-2				0.986*	0.822*	0.853*	0.835*	0.031	0.134	0.105
FIM-3					0.830*	0.855*	0.844*	0.031	0.114	0.084
TIN-1						0.959*	0.970*	−0.001	0.067	0.018
TIN-2							0.974*	−0.027	0.010	−0.007
TIN-3								−0.001	0.040	0.015
VAS-1									0.747*	0.736*
VAS-2										0.777*
VAS-3										

FIM-1, FIM-2, and FIM-3; TIN-1, TIN-2, and TIN-3; VAS-1, VAS-3, and VAS-3 are Functional Independence Measure scale, Tinetti scale, and Visual Analog Scale, respectively, at T1, T2, and T3 time measurement points; *$p < 0.001$

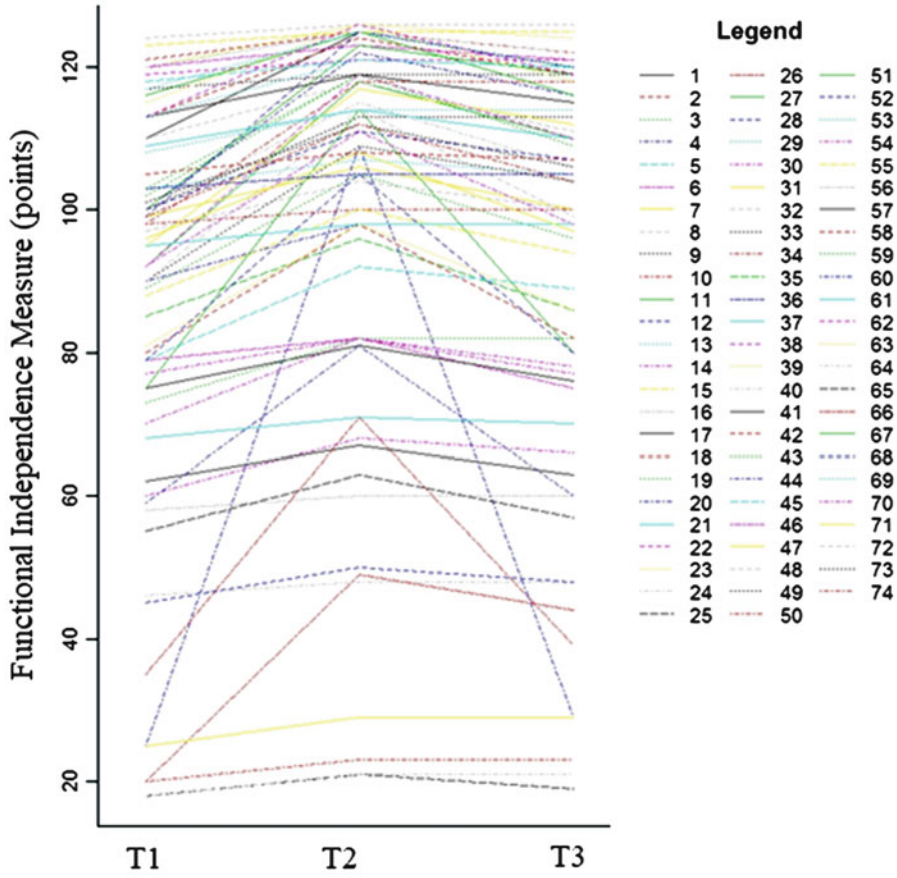

Fig. 1 Evolution of Functional Independence Measure (FIM) over treatment periods; T1 – baseline before treatment; T2 – after 5 months' treatment, i.e., end of treatment; and T3–6 months after the end of treatment

the table shows the correlation matrix examining the inter-dependence between pairs of variables. FIM and TIN scores showed strong positive correlations with AGE, but it was not the same for VAS. Figs. 1, 2, and 3 show the evolution over time of FIM, TIN, and VAS, respectively. These figures as well as Table 1 show that at T3 (6 months after end of treatment) patients got worse. In fact, FIM and TIN scores have a pyramid trend (Figs. 1 and 2), while VAS trend is the opposite (Fig. 2) in most patients.

Consecutive panels of Table 3 show the results of statistical analysis of ANOVA for repeated measures to assess differences among the data of FIM, TIN, VAS, and GHI scales, each obtained at the three time points of measurements. The analysis shows that time has a significant effect in each case. Therefore, the null hypothesis on the equality among the mean data for T1, T2, and T3 was rejected. The *post-hoc* tests show that the mean values of the three time variables were statistically different from each other in case of each scale.

Figure 4 presents the distribution of GHI index at T1 (red), T2 (green), and T3 (blue) time points. The representation shows that the index distribution at T2 is translated horizontally, compared to T1 and T3. This result is confirmed in Table 3 (bottom panel), which illustrates the results of ANOVA for repeated measures concerning the overall health index obtained at these three different time points. The plot confirms a general health improvement at the end of treatment period (T2) and a little decrease in health 6 months after treatment completion (T3).

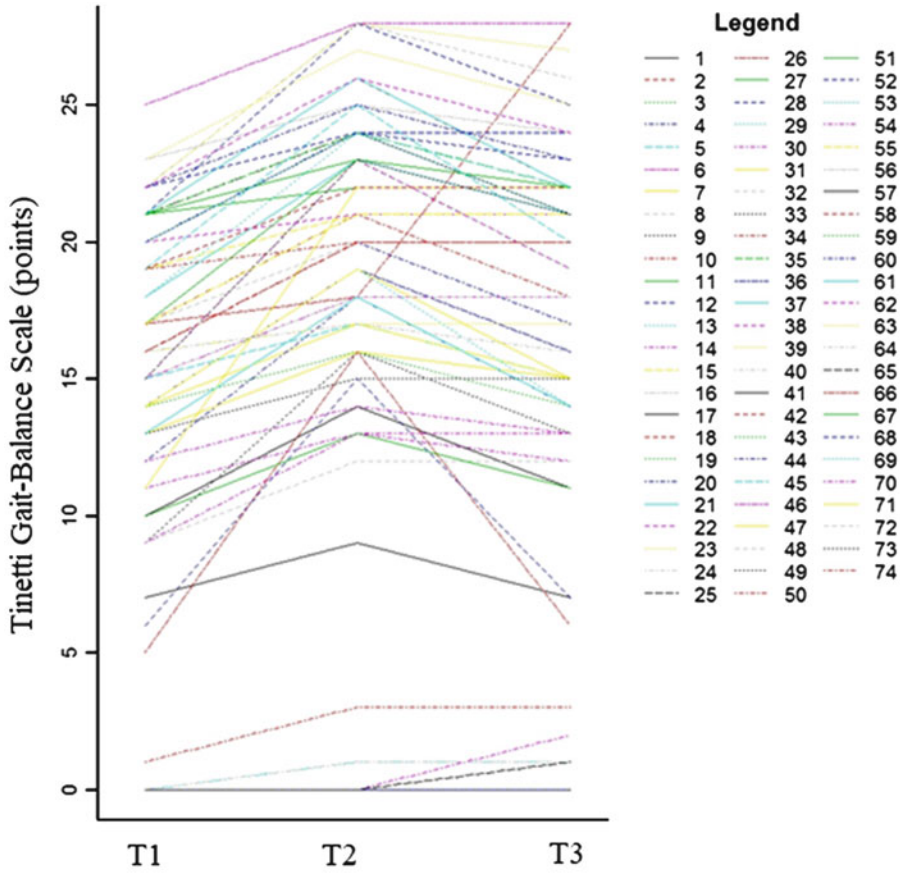

Fig. 2 Evolution of Tinetti Gait-Balance Scale (TIN) over treatment periods; T1 – baseline before treatment; T2 – after 5 months' treatment, i.e., end of treatment; and T3–6 months after the end of treatment

5 Discussion

Immersion in water produces a central redistribution of the blood volume, which decreases neural system activation (Friedman Elliot and Irwin 1997). A decrease in sympathetic activity, accompanied by increased parasympathetic activity, increases blood flow, accelerates cellular metabolism, removes fatty substances, and decreases pain sensitivity by promoting vasodilation and blood circulation (Forestier and Françon 2008). The autonomic nervous system remodeling positively affects the perception pain and fatigue associated with musculoskeletal disorders due mostly to decreasing muscle tension (Yasui et al. 2010). Several studies have highlighted exercise protocols that are associated with improved mobility and walking in neuromotor dysfunction (Pérez de la Cruz 2017; Kim et al. 2016; Lai et al. 2015; Motl et al. 2005). Individuals with neuromotor disabilities should be encouraged to undergo adjuvant therapy to mitigate progressive dysfunction of mobility, especially taking into account the prevailing physical inactivity among such patients.

The Safe Bearing Back aquatic program offers advantages in the treatment of neural and musculoskeletal diseases that cannot be achieved in hydrotherapy consisting of passive immersion only or balneotherapy (Saggini et al. 2008). In the present study, descriptive statistics shows that the scores of all three scales used improved at the end of treatment (T2); the FIM averaged about a 100, the TIN about 18, and the VAS about 5 points. These results show that the degree of self-sufficiency (FIM), walking ability (TIN), and

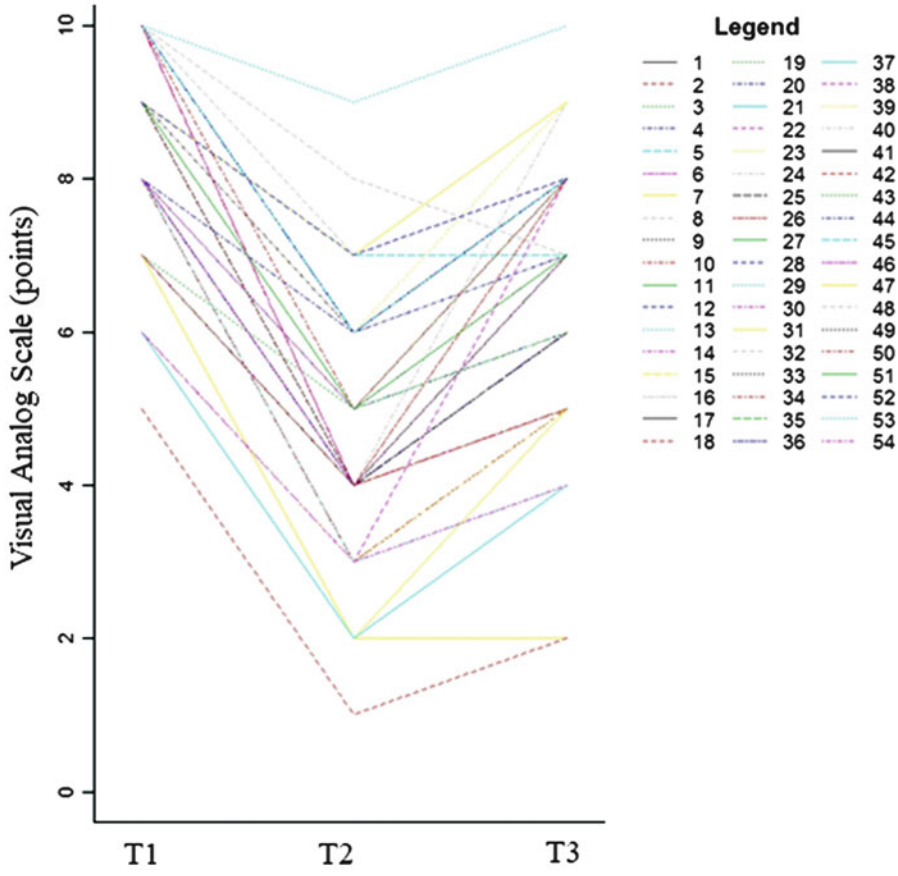

Fig. 3 Evolution of Visual Analog Scale (VAS) over treatment periods; T1 – baseline before treatment; T2 – after 5 months' treatment, i.e., end of treatment; and T3 – 6 months after the end of treatment

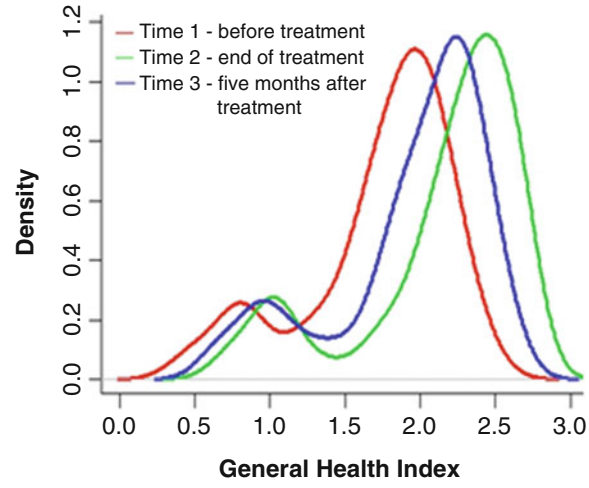

Fig. 4 Evolution of general health index (GHI) distribution over time

Table 3 ANOVA analysis for repeated measures (within) for differences among the scores in FIM, TIN, VAS, and GHI scales, each obtained at three time points of measurements

FIM – Functional Independence Measure					
	DF	SS	MS	F-value	Pr > F
Time	2	18.900	9.449	67.84	< 2e-16*
Residuals	146	20.340	0.139		
Simultaneous tests for general linear hypotheses multiple comparisons of means: Tukey contrasts					
	Estimate	SE	z-value	Pr > |z|	
T2-T1	−0.712	0.061	−11.579	< 1e-06*	
T3-T1	−0.288	0.061	−4.688	6.88e-06*	
T3-T2	0.4228	0.061	6.891	< 1e-06*	
TIN – Tinetti gait-balance scale					
	DF	SS	MS	F-value	Pr > F
Time	2	7.244	3.622	41.62	< 4.97e-15*
Residuals	146	12.205	0.087		
Simultaneous tests for general linear hypotheses multiple comparisons of means: Tukey contrasts					
	Estimate	SE	z-value	Pr > |z|	
T2-T1	−0.441	0.049	−9.096	< 1e-04*	
T3-T1	−0.250	0.049	−5.164	< 1e-04*	
T3-T2	0.191	0.049	3.932	0.000265*	
VAS – visual analog scale					
	DF	SS	MS	F-value	Pr > F
Time	2	363.0	181.5	290.1	< 2e-16*
Residuals	106	66.3	0.63		
Simultaneous tests for general linear hypotheses multiple comparisons of means: Tukey contrasts					
	Estimate	SE	z-value	Pr > |z|	
T2-T1	−3.667	0.152	−24.09	< 2e-16*	
T3-T1	−1.815	0.152	−11.92	< 2e-16*	
T3-T2	1.852	0.152	12.16	< 2e-16*	
GHI – General health index					
	DF	SS	MS	F-value	Pr > F
Time	2	4.529	2.264	299.5	< 2e-16*
Residuals	106	0.801	0.008		
Simultaneous tests for general linear hypotheses multiple comparisons of means: Tukey contrasts					
	Estimate	SE	z-value	Pr > |z|	
T2-T1	0.409	0.167	24.47	< 2e-16*	
T3-T1	0.212	0.167	12.68	< 2e-16*	
T3-T2	−0.197	0.167	−11.79	< 2e-16*	

DF, degrees of freedom; *SS,* sum of squares; *MS*, mean square; *Pr > F*, the significance probability value associated with the F-value; SE, standard error; *Pr > |z|*, the significance probability value associated with the z-value. T1 (baseline before treatment), T2 (after a five-month treatment, i.e., end of treatment), and T3 (6 months after end of treatment); *p < 0.001

subjective pain perception (VAS) all were significantly improved after water microgravity-related treatment (from T1 to T2). In addition, the study underscores that the condition of patients started to decline after stopping of treatment (from T2 to T3), although it still remained at a significantly better level than the baseline one (from T1 and T3). Therefore, considering a moderately long period of 6 months after hydrotherapy cessation, we can state that the neurosomatic and neurophysiological stimulation, resulting from the Safe Bearing Back protocol in the aquatic microgravity environment, is of benefits to patients' autonomy, gait-balance, and the psychoemotional sphere of pain perception, which is also tantamount to improvement in general health status.

The improvement in mobility achieved by the Safe Bearing Back aquatic program and manual therapy can be exploited by clinicians and physiotherapists to promote new strategies for correcting physical agility in dysfunctional patients (Motl et al. 2005). Aquatic exercise therapy improves mobility in all types of neuromotor disabilities, particularly in progressive and resistant to pharmacotherapy cases (Rekand 2010). The present findings are in line with those of Baena-Beato et al. (2014) who have demonstrated that a program of intense, five sessions a week, rehabilitation in a water microgravity environment is well tolerated and produces significant improvements in both pain perception and quality of life in patients with chronic pain (Baena-Beato et al. 2014). Moreover, LeFort and Hannah (1994) have highlighted that aerobic exercise in the aquatic environment is beneficial for both cardiovascular and articular mobility, and for psychological aspect as it reduces anxiety and enhances mood that is constantly low in chronic, particularly neurodegenerative, conditions. Giaquinto et. al. (2007) have reported that gait in the physically fit elderly assumes characteristics comparable to those in younger persons during hydrotherapy. Likewise, Alcade et al. (2017) have reported beneficial effects of aquatic rehabilitation exercises in patients with knee osteorthritis. The strength of the present study was to demonstrate the effectiveness of a Safe Bearing Back Sequential Motor Method with respect to specific outcomes such as stroke, balance of autonomy, and pain in patients with neuromotor disabilities. The weakness of the study is represented by a non-complete homogeneity of the sample group concerning individual pathologies and different age of patients belonging to the same group. Nonetheless, we believe that the findings lend support for those other studies that point to the applicability of a specific training in the aquatic microgravity in neuromotor disabilities.

6 Conclusions

Aquatic exercise can refer to pool therapy, hydrotherapy, or balneotherapy. Hydrotherapy is frequently applied to patients with painful neurological or musculoskeletal alterations, because the heat and floatability of water can block nociceptors by acting on thermal receptors and mechanoreceptors and exert a positive effect on spinal segmental mechanisms (Bellomo et al. 2012; Geytenbeek 2002). Warm water can also increase the blood flow, helping to dissipate allogeneic chemicals and to enhance muscle relaxation. Finally, the hydrostatic effect of water can alleviate pain by reducing peripheral edema and sympathetic nervous system activity. A systematic review on crenobalneotherapy in patients with limb osteoarthritis found that it reduces pain and improves function and quality of life (Forestier and Françon 2008). These water features allow the physiotherapist to work differently from treatments outside the water and to propose exercises that would not be possible in a terrestrial environment, such as articular techniques associated with tissue manipulation in water (Oh et al. 2015). The main aim of the present article was to determine the effectiveness of hydrotherapy to modify pain, quality of life, and other symptoms in neuromotor disease (Marinho-Buzelli et al. 2017; Konrad et al. 1992). The findings demonstrate appreciable improvements after treatment in both the Tinetti Gait-Balance Scale and the Visual Analog Scale, which were maintained, albeit gradually abating, during the six-month-long follow-up period. Even though there was a significant reduction of the beneficial effects at the end of the follow-up, corrective changes in the gait, balance, autonomy, and pain remained, to an extent, compared with the baseline level present before the commencement of treatment. Therefore, given the clearly advantageous effects of hydrokinesitherapy with the Safe Bearing Back method employed in this study, we suggest that five therapeutic cycles for each patient, could be administered not in 5 months, but distributed over the solar year. That might ensure a longer term maintenance of improvement in the health condition of patients with neuromotor and neurological disabilities, and in effect lower both social and economic costs of patient care. Regarding the General Health Index, our future research will focus on the use of new functional tools to analyze the

positive trend over time (Maturo and Di Battista 2018) and the significance of changes in the advanced methodological context (Di Battista et al. 2016).

Competing Interests The authors declare no competing interests in relation to this article.

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